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ABSTRACT

This report provides empirical results of attempts to achieve consistency of estimates between two National Center for Education Statistics (NCES) surveys. These surveys are the 1991- 92 Private School Survey (PSS) and the Private School Component of the 1990-91 Schools and Staffing Survey (SASS). Consistency was sought in the numbers of schools, teachers, and students from these two sources. Comparisons are made among statistical and computational procedures that might serve to bring about the desired consistency. The complex nature of the survey designs is considered, and definitional problems are explored. Consequences of discrepancies and adjustments are discussed. The results of tests of nine typologies are presented. For some typologies (Catholic Parochial, Catholic Private, Conservative Christian, and Other Affiliated) the operational assessment shows the impact of adjustment on the SASS at least did no apparent harm, and an independent assessment shows that it might have been beneficial to accuracy. For three other typologies (Other Unaffiliated, Nonsectarian Regular, and Nonsectarian Special) the Generalized Least Squares (GLS) adjustment may have caused severe problems. Overall, results suggest that the use of a modified GLS reweighting, even when beneficial, does not make much of a positive difference beyond achieving consistency with PSS. Other methods appear needed to take advantage of the opportunity offered by having both surveys fielded for the same year. An appendix discusses a media GLS method. (Contains 19 tables, 36 figures, and 23 references.) (SLD)

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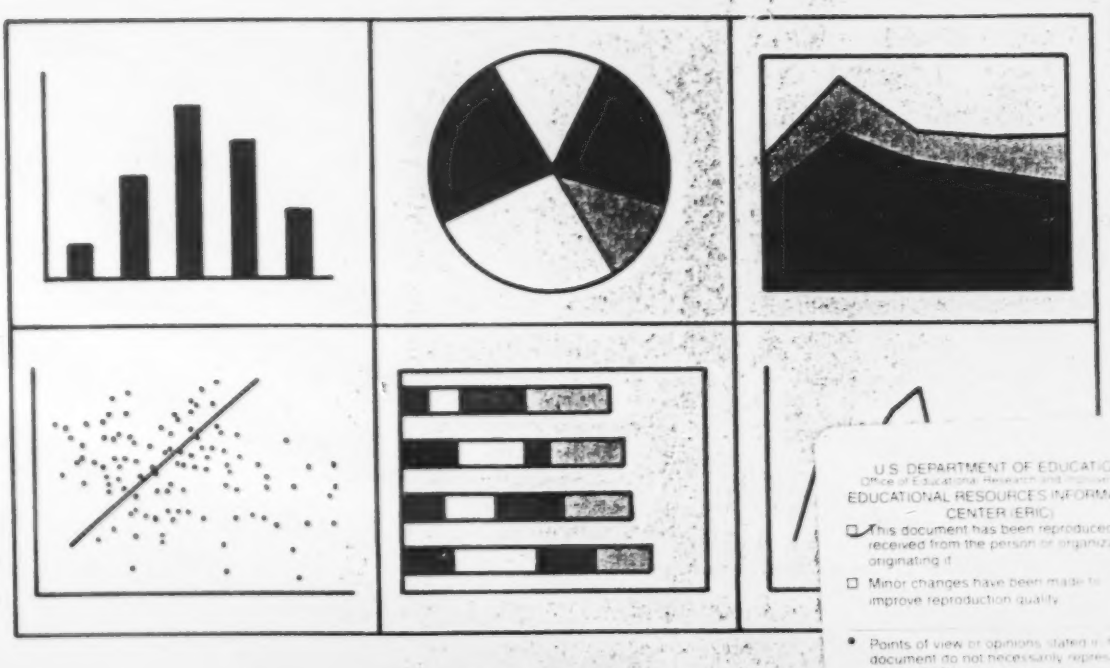
Working Paper Series

Intersurvey Consistency in NCES

Private School Surveys

Working Paper No. 95-16

April 1995



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Intersurvey Consistency in NCES

Private School Surveys

Working Paper No. 95-16 April 1995

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April 1995

FOREWORD

Each year a large number of written documents are generated by NCES staff and individuals commissioned by NCES which provide preliminary analyses of survey results and address technical, methodological, and evaluation issues. Even though they are not formally published, these documents reflect a tremendous amount of unique expertise, knowledge, and experience.

The ***Working Paper Series*** was created in order to preserve the valuable information contained in these documents and to promote the sharing of valuable work experience and knowledge. However, these documents were prepared under different formats and did not undergo vigorous NCES publication review and editing prior to their inclusion in the series. Consequently, we encourage users of the series to consult the individual authors for citations.

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INTERSURVEY CONSISTENCY IN NCES PRIVATE SCHOOL SURVEYS

Prepared for
National Center for Education Statistics

April 1995

Submitted by

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1. OVERVIEW AND BACKGROUND

This report provides empirical results of attempts to achieve consistency of estimates between two National Center for Education Statistics (NCES) surveys. These surveys are the 1991-92 Private School Survey (PSS) and the Private School Component of the 1990-91 Schools and Staffing Survey (SASS). Consistency was sought in the numbers of schools, teachers, and students from these two sources.

Comparisons have been made among statistical and computational procedures that may serve to achieve the desired consistency between estimates. The complex nature of the PSS and SASS sample designs has been considered, as well as any definitional differences which might exist between the surveys. In addition, potential benefits and the possibility of harm have also been addressed.

The goal of this overview section is to state the problem being addressed and why it may be important (in subsection 1.1). An attempt is also made here to give sufficient background on the PSS so that the context and statistical issues are clear (in subsection 1.2). For the same reasons, the design of the SASS private school component is discussed as well (in subsection 1.3). To keep the treatment self-contained, definitions have been provided (subsection 1.4).

In the following sections (sections 2 to 4) the adjustment alternatives are covered and the main method being used is described in great detail (in section 2). Results from nine independent applications (by typology) are analyzed in depth (section 3); a concluding section, summarizing the work done and making some recommendations, ends the basic presentation (section 4). References are included and an appendix documenting a secondary approach is also provided.

1.1 VALUE OF STUDYING INTERSURVEY CONSISTENCY

For the first time, in 1993-94, the private school component of the Schools and Staffing Survey (SASS) and the Private School Survey (PSS) were fielded in the same school year. Even though these two surveys measure some of the same variables, the results between the surveys will not agree.

As the PSS is used for the SASS sampling frame, the PSS results are likely to be more accurate. Under these circumstances, it makes sense to explore whether introducing PSS totals into SASS might lead to improvements. Traditional poststratification methods exist to employ auxiliary information at the estimation stage in surveys. These, however, cannot be applied to SASS without modification.

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In particular, PSS and SASS both measure numbers of schools, numbers of teachers, and numbers of students. Conventional simple or raking ratio adjustment procedures could be used to adjust sample weights so that the SASS estimates agreed with PSS for each of the three totals separately (e.g., Oh and Scheuren 1978). Such approaches do not work, though, if the weights are to be adjusted so that all three SASS estimates agree simultaneously. Other methods in the Generalized Least Squares (GLS) family, however, are available and, although new within an NCES framework, have proven to be of value elsewhere.

1.2 PRIVATE SCHOOL SURVEY (PSS) DESIGN

The Private School Survey (PSS) is designed to collect data from all private schools in the 50 states and the District of Columbia. The survey has been collected periodically by the U.S. Bureau of the Census for the National Center for Education Statistics (NCES). Both a list and an area frame are employed. The description which follows basically has been taken from Broughman et al. 1994.

1.2.1 List Frame.-- A commercial list from Quality Education Data (QED) served as the base list for the private school universe in 1987 and 1989. The list is compiled from handbooks, annual directories, and other materials which list private schools. The QED identifies private schools in all 50 states and the District of Columbia. It describes each school by address, phone number, grade level, enrollment, and number of teachers. This list is used primarily by commercial companies for marketing books, supplies, and other educational material. NCES checked all schools on the QED file to determine their eligibility for inclusion on the list. Many of the schools on the QED base list did not meet the criteria. (See school definition in section 1.4, see also table 1 for the number of eligible and ineligible schools.)

To improve coverage of private schools, NCES requested and collected membership lists from 20 private school associations and denominations. NCES and Census also collected an updated list from QED and lists of private schools from the 50 states, the District of Columbia, and Josten's, a company which sells school rings. Schools on private school association membership lists and state lists were compared to the base list. Any school on an association or denomination list, state list, the QED update list, or Josten's which did not match a school on the base list was added to the NCES private school universe list. As a result of these efforts, approximately 5,000 schools were added in 1991, for a total of 28,431 schools on the NCES private school universe list.

1.2.2 Area Frame.-- Additional schools (368) were identified through an area search of randomly selected primary sampling units (PSUs).

The 1989 PSS area frame sample consisted of 123 PSUs from two sets of sample PSUs. The first set was a subsample of 60 PSUs selected from the PSUs in

the earlier Private School Survey. A second set of 64 additional sample PSUs was selected independently of the first set of 60 PSUs. One PSU in the sample of 64 was also drawn in the first sample of 60 PSUs, thus resulting in a total of 123 PSUs. The total number of PSUs in the United States was used in drawing the second set of PSUs. This design was intended to improve the reliability of estimates of change.

Similar in design to the 1989 PSS area frame, the 1991 area frame consisted of 123 PSUs from two sets of sample PSUs. The first set is a subsample of 64 PSUs (56 noncertainty and 8 certainty PSUs); the second set of 60 noncertainty PSUs was selected independently of the PSUs in the earlier sample. One PSU in the sample of 60 was also drawn in the first sample of 64 PSUs. The total number of PSUs in the United States was used in drawing the second set of PSUs.

The 1991 strata were defined by (1) census region (four levels: Northeast, Midwest, South, and West); (2) metro/nonmetro status (two levels); and (3) whether or not each PSU's private school enrollment exceeded the median private school enrollment of the other PSUs in the same census region/metro status strata (two levels).

1.2.3 Combined List and Area Samples.-- Data collection for the 1991-92 PSS was completed in January 1992. The final response rate was 98 percent. Of the 28,799 schools in the sample, some 4,517 cases were considered out-of-scope. Weighted and unweighted counts are shown below for both the list and area portions of the survey (where the weighted data have been adjusted to account for nonresponse).

Table 1 -- List and Area Components of PSS

	Unweighted	Weighted
Total	28,799	25,998
Out of Scope:		
List frame	4,504	0
Area frame	13	0
In Scope:		
List frame	23,927	23,927
Area frame	355	2,071

1.3 PRIVATE SCHOOL DESIGN OF SCHOOLS AND STAFFING SURVEY (SASS)

In the 1990-91 SASS there were 3,280 private schools selected using a dual frame approach. A list frame was the primary private school frame, and an area frame was used to

find schools missing from the list frame and thereby compensate for the coverage problems of the list frame. The description which follows basically has been taken from Kaufman and Huang 1993.

1.3.1 List Frame.-- The 1990-91 SASS list frame used for private schools was the 1989 Private School Survey (PSS) list frame. NCES initiated PSS to build a universe frame of private schools. The PSS list frame universe is based on the 1988-89 QED private school list, updated with private school association lists given to the Bureau of the Census in the spring of 1989. Various private school associations were asked to supply lists of their schools. Twenty such lists were received. These lists were matched with the QED list and any association list school not found on the QED file was added to the frame. Before sampling, duplicate schools were excluded from the frame. Schools that only taught prekindergarten, kindergarten, or adult education were also removed. Totals from the 1990-91 SASS list frame are shown in table 2.

1.3.2 Area Frame.-- The area frame sample consisted of two sets of sample PSUs: (1) a subsample of the 1988 SASS area frame PSUs; and (2) a sample of PSUs selected independently from the 1988 SASS sample. The 1988 SASS sample PSUs were selected systematically with probabilities proportional to the square root of enrollment from each of sixteen strata defined by Census region, metro/nonmetro status, and high or low percent enrollment in private schools. By maintaining a fifty percent overlap of PSUs, the reliability of estimates of change was maintained at a reasonable level, while reducing respondent burden.

1.3.3 Combined List and Area Samples.-- Data collection for the 1990-91 SASS was completed in the spring of 1991. The final response rate for private schools was considerably less than for the PSS (at 83.9 percent). Of the 3,280 schools in the sample, some cases were considered out-of-scope. Weighted and unweighted counts are shown below for both the list and area portions of the survey (where the weighted data have been adjusted to account for nonresponse).

Table 2 -- List and Area Components of SASS

	Unweighted	Weighted
Total	3,280	24,557
Out of Scope:		
List frame	130	0
Area frame	70	0
In Scope:		
List frame	2,547	19,401
Area frame	533	5,156

It may be worth commenting that the list portion of the PSS, as a universe count, is definitely to be relied upon in any attempts at achieving intersurvey consistency. The area portions of both the PSS and SASS are samples, suggesting that some combination of the two might be preferable to just relying on the PSS alone.

Table 3 -- Area Components of PSS and SASS Compared

	PSS	SASS
Unweighted	355	533
Weighted	2,071	5,156

Table 3 sharpens this observation by comparing the area components of PSS and SASS shown in tables 1 and 2 above. Notice that the two surveys have area samples that are similar in size. Perhaps a simple weighted combination of the two area estimates might be better in a mean squared error sense than simply controlling on the PSS total. In particular, if we ignore differences in design (and survey date) between PSS and SASS, a combined estimate might be formed as

$$(1/(1+R))(5156)+(1-(1/(1+R)))(2071)$$

where the weighted totals shown are from SASS (5156) and PSS (2071) respectively and R is the ratio of PSS to SASS sample sizes. In this case

$$R=355/533=0.666;$$

hence the "best" estimate is 3923.

In this report, however, the PSS totals were taken as fixed and known with certainty. In the application for 1993-94, though, other alternatives might be considered.

1.4 SOME COMMON VARIABLES AND THEIR DEFINITIONS

Listed below are definitions of the key variables used in this report. These have been taken from several NCES reports (notably Broughman et al. 1994 and McMillen and Benson

1991). The typology classification is listed first. Definitions for school, teacher, student, and community type follow.

1.4.1 Typology.-- For the private school population, a typology exists which starts with the categorization Catholic, Other Religious, and Nonsectarian, and further subdivides each group into three additional groups:

Catholic
- Parochial
- Diocesan
- Private

Other Religious
- Affiliated with a conservative Christian school association
- Affiliated with national denomination or other religious school association
- Unaffiliated

Nonsectarian
- Regular programs
- Special emphasis
- Special education

Among Catholic schools, the governance categories (Parochial, Diocesan, Private) are strongly tied to differences in curriculum, student population characteristics, program emphasis, and sources of revenue.

In the case of Other Religious schools, recent work documents major differences in decision-making, educational goals, revenue, and enrollment trends between denomination schools (i.e., Lutheran, Jewish, Seventh-day Adventist) and those nondenominational schools affiliated with a Conservative Christian school association (e.g., Accelerated Christian Education, American Association of Christian Schools, Association of Christian Schools International, Oral Roberts Educational Fellowship). Schools in this type are commonly known as evangelical or fundamental, and are not tied to a denomination per se, but rather are governed by a single church, a foundation, or a local society. A third Other Religious category, Unaffiliated, is suggested to capture those religious schools which affiliate with neither a national denomination nor with a conservative Christian school association.

The three nonsectarian school categories are determined not by governance but by program emphasis. This classification disentangles private schools offering a conventional academic program (Regular) from those which either serve special needs children (Special Education) or provide a program with a Special Emphasis (e.g., arts, vocational, alternative).

1.4.2 Private School.-- A school is an institution for instruction which has (1) a minimum school day of four hours per day, (2) a minimum of 160 days per year, (3) at least a first grade or higher, and (4) one or more teachers. A private school is an institution which provides instruction for any of grades 1-12, has one or more teachers to give instruction, is not administered by a public agency, and is not operated in a private home.

1.4.2 Teacher.-- In general, any full-time or part-time teacher whose school reported that his or her primary assignment was teaching in any of grades K-12. For this report, however, only full-time teachers are considered.

1.4.3 Student.-- Individuals identified in the PSS or SASS as enrolled in a private school for instruction in a prekindergarten, kindergarten, grades 1-12, ungraded or postsecondary class. Broughman et al. 1994 excludes prekindergarten and postsecondary students, so totals here are not completely comparable. Ordinarily, these totals should be comparable to obtain the maximum benefit from the reweighting done. However, since the present task was simply to research methods, such a step was not felt to be necessary here; it would be done in any real application.

1.4.4 Community Type.-- Community type was based on the school's mailing address matched to Bureau of the Census data files containing population density data, Standard Metropolitan Statistical Area (SMSA) codes, and a Census code defining urban and rural areas. This approach is believed to provide a more accurate description of the community than the respondent's reported community type (as used, for example, in the Schools and Staffing in the United States: A Statistical Profile, 1987-88 (NCES 92-120). For the present purpose, the CCD locale codes were aggregated into three community types, to parallel the Schools and Staffing in the United States: A Statistical Profile, 1990-91 (NCES 93-146). The definitions for each of these are shown below.

- Central City includes urbanicity locale codes Large City and Mid-size City. (A "Large City" is the central city of a Metropolitan Statistical Area (MSA) with a population greater than or equal to 400,000 or a population greater than or equal to 6,000 people per square mile. A "Mid-size City" is a central city of an MSA with a population of less than 400,000 and a population density of less than 6,000 people per square mile.)

- Urban Fringe/Large Town includes urbanicity locale codes Urban Fringe of Large City, Urban Fringe of Mid-size City, and Large Town. (The "Urban Fringe of Large City" is a place within an MSA of a Large Central City and defined as urban by the Census Bureau. The "Urban Fringe of Mid-size City" is a

place within an MSA of a Mid-size Central City and defined as urban by the Census Bureau. A "Large Town" is a town not within an MSA, with a population greater than or equal to 25,000.)

- Rural/Small Town includes urbanicity locale codes Small Town and rural. (A "Small Town" is a town not within an MSA, with a population of less than 25,000 and greater than or equal to 2,500 people. "Rural" is a place with less than 2,500 people and coded rural by the Census Bureau.)

2. INITIAL ATTEMPTS AT ACHIEVING INTERSURVEY CONSISTENCY

For NCES Private School Surveys, alternatives do exist which permit simultaneous consistency or near consistency in totals for schools, teachers, and students. In particular, the Generalized Least Squares (GLS) techniques advocated by Deville and Särndal 1992 can be used, as in Imbens and Hellerstein 1993. While the asymptotic properties of GLS and GLS-like estimators are attractive, their finite sampling properties are not necessarily desirable. Possible operational concerns with GLS procedures include: (1) some of the resulting weights may be less than one (and may be negative); (2) the procedure may be difficult to implement (when excessively small weights exist); and (3) the effect on estimates not directly adjusted is unknown (and could be harmful).

The initial work on GLS estimators dates at least back to Deming and Stephan 1940. A nearly complete set of references through most of the 1970s can be found in Oh and Scheuren 1978b. Among the most important of these is that by Ireland and Kullback 1968, which gives the first convergence proof for the original Deming-Stephan algorithm.

A selection from major recent papers includes work by Bankier 1990, Deville and Särndal 1992, Deville et al. 1993, Fuller et al. 1994, Imbens and Hellerstein 1993, Little 1991, and Little and Wu 1991. The recent book, entitled *Model Assisted Survey Sampling*, by Särndal et al. 1992 is an important source, too. (See references.)

Except for Oh and Scheuren 1978a and Imbens and Hellerstein 1993, most GLS applications covered have been univariate in nature. In the SASS setting, the problem is inherently three-dimensional: Schools, Teachers, and Students--each of which needs to agree with an independent PSS total.

In the main body of this report only one alternative will be covered: a variant of the approach in Imbens and Hellerstein 1993, as suggested independently by Burton 1989. In the appendix, however, another variant is discussed that was also considered, and still more are taken up in the concluding section where areas for future study are considered.

2.1 MODIFIED GENERALIZED LEAST SQUARES (GLS) ESTIMATION

To discuss the basic algorithm employed in Generalized Least Squares, it is necessary to define some notation; in particular

w_i is the original SASS Private School base weight for the ith SASS observation, $i=1,\ldots,n$.

t_i is the SASS total of teachers for the ith SASS observation, $i=1,\ldots,n$.

s_i is the SASS total of students for the ith SASS observation, $i=1,\ldots,n$.

N is the total estimated number of schools, as given by PSS.

T is the total estimated number of teachers, as given by PSS.

S is the estimated total number of students, as given by PSS.

In reweighting SASS, three constraints are imposed on the new weights u_i,

$$\Sigma\, u_i = N$$

$$\Sigma\, u_i t_i = T$$

$$\Sigma\, u_i s_i = S$$

For our application, the new weights u_i, subject to these constraints, are to be chosen (as in Burton 1989) to minimize a loss function which can be written as the sum of squares

$$\Sigma\, (u_i - w_i)^2$$

This is perhaps the simplest and most straightforward loss function that might be chosen. Motivating it here is outside our present scope, except to say that the sensitivity of the final results to the loss function chosen (e.g., Deville and Särndal 1993 and Deville et al. 1993) seems not to be too great (but this is, in part, an application issue and will be among the areas for future study, as set forth at the end of this report).

The usual Lagrange multiplier formulation of this problem yields after some algebra that the new weights are of the form

$$u_i = w_i + \lambda_1 + \lambda_2 t_i + \lambda_3 s_i ,$$

where the λs are obtained from the matrix expression

$$\underline{d} = M\underline{\lambda}$$

with the vector $\underline{d}$ consisting of three elements, each a difference between the corresponding PSS and SASS totals for schools (first component), teachers (second component), and students (third component); in particular

$$N - \Sigma w_i$$

$$T - \Sigma w_i t_i$$

$$S - \Sigma w_i s_i$$

where the summations are over the SASS sample observations and the quantities: N, T, and S are known PSS totals for schools (N), teachers (T), and students (S) respectively.

The matrix M is given by

$$\begin{matrix} n & \Sigma t_i & \Sigma s_i \\ \Sigma t_i & \Sigma t^2_i & \Sigma t_i s_i \\ \Sigma s_i & \Sigma t_i s_i & \Sigma s^2_i \end{matrix}$$

and $\underline{\lambda}$ is the vector of unknown GLS adjustment factors obtained from

$$\underline{\lambda} = M^{-1}\underline{d}$$

(Notice that the M matrix is based solely on the unweighted sample relationships among schools, teachers, and students. This is not an essential feature of our approach; a weighted version of the M matrix could have been used, as is discussed later in this report.)

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2.2 ILLUSTRATIVE EXAMPLE

Considering the following example may help illustrate the differences between methods. First, suppose a SASS subgroup has ten observations (even though this is probably too small, the methods discussed here are to be applied). Second, the observations appear below as column vectors where the components

$$\begin{matrix} x \\ y \\ z \end{matrix}$$

correspond to schools, teachers, and students respectively. In particular, the SASS data are

1	1	1	1	1	1	1	1	1	1
1	2	3	4	5	6	7	8	9	10
1	6	2	7	3	8	4	9	5	10

Aggregating the three SASS components yields

$$\begin{matrix} 10 \\ 55 \\ 55 \end{matrix}$$

Third, suppose the PSS totals for this subgroup are

$$\begin{matrix} 10 \\ 50 \\ 50 \end{matrix}$$

Notice, the SASS school total has already been set equal to that in the PSS. This has been done so that the example starts where a standard SASS estimation procedure might end.

For the "modified GLS" the elements of the matrix M and the vector $\underline{d}$ need to be obtained. Thus, $\underline{d}$ is

$$\begin{matrix} 10 - 10 = & 0 \\ 50 - 55 = & -5 \\ 50 - 55 = & -5 \end{matrix}$$

For the matrix M, after some calculation, the values are

10	55	55
55	385	355
55	355	385

For the inverse of M^{-1}, the values turn out to be

.5481	-.0407	-.0407
-.0407	.0204	-.0130
-.0407	-.0130	.0204

Thus, solving

$$\underline{\lambda} = M^{-1}\underline{d}$$

the vector is $\underline{\lambda}' = (.4074, -.0370, -.0370)$ and the modified GLS weights are of the form

$$u_i = w_i + .4074 - .0370t_i - .0370s_i$$

2.3 DISCUSSION

So far the GLS algorithms have been discussed as if the issues were simply computational. In point of fact, the real challenges arising in any SASS implementation require statistical judgments. Among these are:

- Deciding at which level of SASS the constraints are to be imposed. For example, from a subject-matter perspective, it seems appropriate to do GLS estimation separately within the nine private school types (as done for this report). For some of the larger typologies, even finer groupings might be attempted (school level or community type). At what point will the potential benefits of a GLS adjustment outweigh the harm?

- Avoiding GLS weights u_i that are negative or too small (i.e., given that each SASS observation always represents at least itself, a natural requirement to impose is that $u_i \geq 1$ for all i). This concern is particularly troublesome because of the seemingly ad hoc flavor of what may be needed to get acceptable weights (however, see Huang 1978).

While the guidance of earlier GLS practice elsewhere is available, perhaps neither of these challenges can be resolved for SASS, except "in the doing." Indeed, concepts like "benefit" and "harm" are not uniquely defined. In the formulation here, however, "benefits" will include not only intersurvey consistency between SASS and PSS but also the usual criteria such as reductions in the mean square error of estimates not constrained directly. The concept of "harm" is more elusive still. Among the factors to consider are obvious ones such as:

- How difficult (expensive) is the method to implement, as well as to explain?
- How sensitive are unconstrained estimates to seemingly small but arbitrary decisions in the way the method is applied?

A measure of "harm" that grows directly out of GLS is to look at what is happening to the variances of the weights as successive constraints are applied. A variant of this is to examine the ratio of the sums of the squared weights (where the adjusted weight is divided by the original weight),

$$\Sigma u_i^2 / \Sigma w_i^2$$

The intuitive notion here is that the larger this ratio is the greater the possible harm to a statistic not correlated with the quantities being constrained. To look at the mean square error of the GLS estimators obtained in SASS, a direct comparison will also be made (in section 3 below) to selected comparable PSS quantities not directly used in the GLS process. This assessment will involve data by community type and school size, items not used in the GLS adjustment.

3. RESULTS OF GLS APPLICATIONS BY TYPE OF SCHOOL

For the nine major types of private schools, there has been an attempt to employ the modified GLS algorithm discussed in section 2. These applications were done separately and have been reported on as such here.

The approach taken in all instances is the same. The presentation begins with an overall description for a typology of the PSS and original SASS totals for schools, teachers, and students; next there is an indepth look at the relationship between teacher and student totals in the two sources. This is followed by a documentation of how the weight adjustment factors, the λs, were derived (plus what they mean for the particular typology). The actual operating characteristics of the resulting weights are then extensively commented on. An independent assessment (by community type and school size) of the adjustments on variables not directly impacted concludes the treatment.

Each typology can be read as a stand-alone case study. Familiarity with scatterplot matrices (e.g., Cleveland 1993) is assumed; beyond that, no special analytic tools are used that are not either well-known or explained as they are taken up.

Comparisons across typologies are left to Summary and Recommendations (section 4). It is fair to say, though, that on the whole the GLS calculations were fairly successful, especially given that the SASS and PSS data were not for the same year. On the other hand, "the jury is still out" on what beneficial impacts, if any, there were for SASS estimates beyond achieving a limited consistency with PSS.

3.1 CATHOLIC PAROCHIAL TYPOLOGY

The Catholic Parochial typology represents the largest single type of private school. In the 1991-92 Private School Survey, there were an estimated 5,485 Catholic Parochial schools, equaling 21.1 percent of the private school total for that year.

In table 1.1, SASS and PSS estimates are shown for schools, teachers, and students. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that the schools total is already very close (within one percent), but that SASS has many fewer teachers and students than are shown in PSS (seven percent to eight percent less).

Table 1.1 -- 1991-92 PSS and Original 1990-91 Catholic Parochial SASS Totals Compared

	PSS	SASS
Schools	5,485	5,437
Teachers	68,742	63,638
Students	1,543,784	1,424,291

(Note: The numbers here may be different than the numbers in table 1.2 because of rounding.)

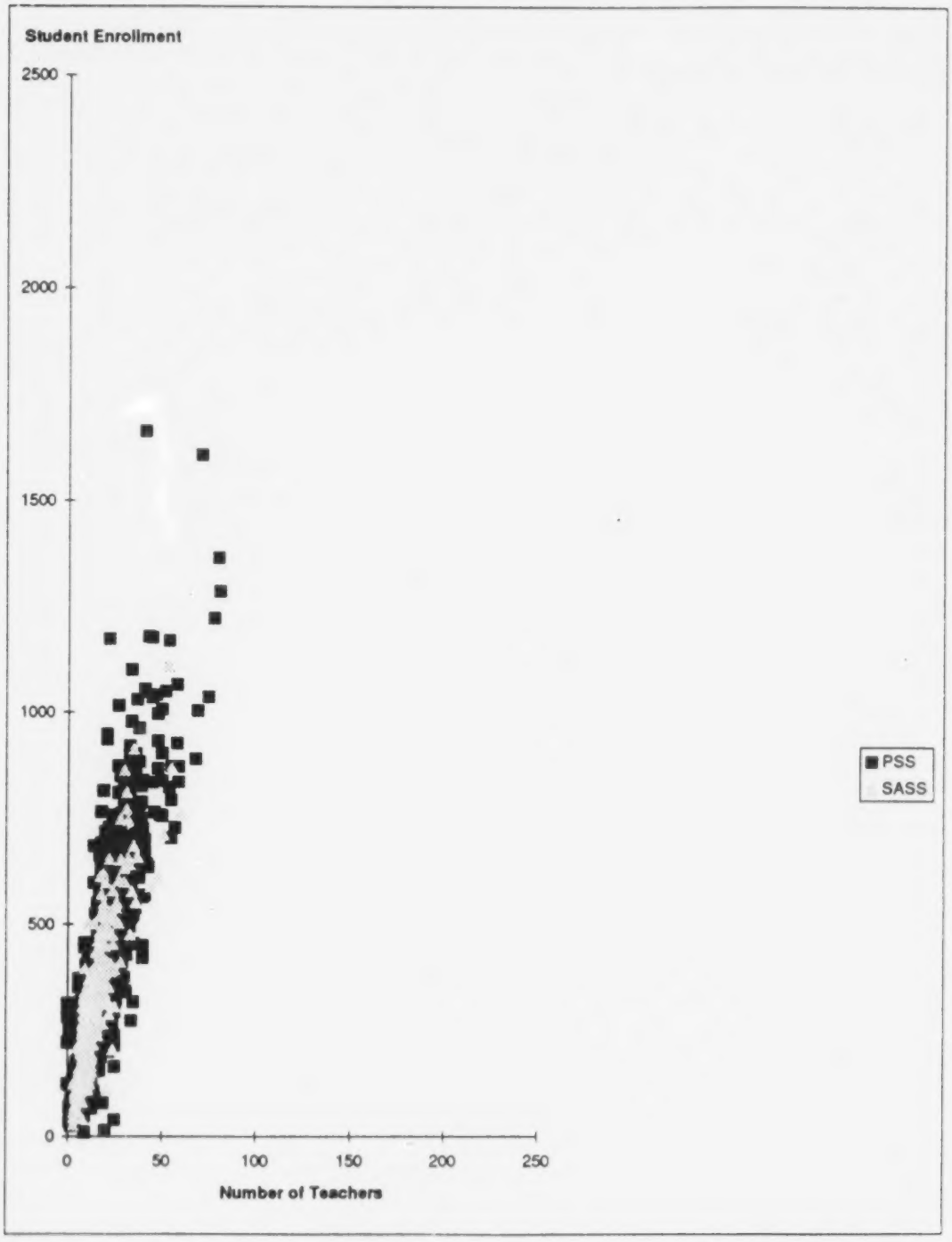
To set the stage for the calculations that follow, look at figure 1.1, which provides a scatterplot of student enrollment by number of teachers (see next page). The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. As can be seen, the SASS data points lie within the parameters of the PSS data points, and along the same axis. In fact, the student/teacher ratios are 22.5 for PSS and 22.4 for SASS.

These surveys are not for the same year but, if they were, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

3.1.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

Figure 1.1 -- **Catholic Parochial**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

needed to be solved for the 352 sample cases in the Catholic Parochial typology from SASS. It can be derived from table 1.1 above that $\underline{d}$ is

$$\begin{matrix} 48 \\ 5{,}104 \\ 119{,}493 \end{matrix}$$

The matrix M was obtained by tabulating the 1990-91 SASS file for the Catholic Parochial schools in the SASS sample. The values obtained are

$$\begin{matrix} 352 & 4{,}720 & 102{,}196 \\ 4{,}720 & 88{,}058 & 1{,}789{,}015 \\ 102{,}196 & 1{,}789{,}015 & 39{,}302{,}220 \end{matrix}$$

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (-3.030, -0.019, 0.012)$ and the modified GLS weights are of the form

$$u_i = w_i - 3.030 - .019t_i + .012s_i$$

Notice that all the original weights are lowered (by about three); depending on the teacher and student counts in the sampled school, they may be increased again or lowered further (usually they would not be lowered further since the teacher and student coefficients are of the same order, and, in virtually all schools, the student totals are many times larger). These additional school-by-school adjustments do not appear to be too drastic--given that the coefficients on the teacher and student counts are so small. Looking just at the equation, concerns about negative weights arise, but these did not materialize as will be seen below. Finally, while the values for $\underline{\lambda}$ are only shown to three decimal places, the calculations have been carried out in double precision.

3.1.2 Operational Characteristics.-- The GLS reweighting seems to have worked well. To justify this observation, we will look at several diagnostics. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that for the original weights, w_i? The ratio of these two quantities is a good bit less than one (about 0.73), implying that minimal or no harm may have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process. Some concerns exist, however, because the weight variance may have shrunk too much, weakening the presumed efficiencies gained from the initial stratification.

The range of the weights is another measure worth examining. This range shows the spread of the weights and any attenuation that may have occurred. Given the variance results above, it is not surprising to find that the range of the GLS weights is shorter than for the original weights, albeit not by much.

Original	2.5 to 33.7
GLS	2.8 to 31.3

Why? Both the teacher and student counts in SASS were below those in PSS (and by roughly the same proportion) while the school totals were fairly close. What the modified GLS estimation did was to increase the usually smaller weights of the larger schools and, to keep the school totals close to equal, it lowered the usually larger weights of the smaller schools. Overall this reduced the variance of the GLS weights and narrowed their range, relative to those originally on the file.

Figures 1.2 and 1.3 illustrate other operating characteristics of the original and GLS weights. Figure 1.2 shows weight increases for schools with more teachers and the corresponding decline in weights for schools with smaller numbers of teachers. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) Incidentally, there is a corresponding decline in the absolute value of the simple correlation between the teacher total and the school weight (from about -0.65 to -0.40).

Figure 1.3 shows the same pattern observed earlier--this time by enrollment size--where the GLS weight increases for schools with more students and declines for schools with smaller numbers of students. Again, there is a corresponding (absolute) decline in the simple correlation between enrollment and the school weight (from about -0.55 to -0.20).

We will comment on one more panel in figures 1.2 and 1.3, the scatterplot of GLS weights versus original weights. Not surprisingly, a strong relationship exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.1.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Catholic Parochial Typology are available in table 1.2 and figure 1.4. Table 1.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 1.4 is another version of the data in table 1.2.

On a cell-by-cell basis, the relationship between the two versions of SASS is fairly stable and predictable (R^2 = .99). Each is also closely related to the PSS.

Originally weighted SASS	vs PSS (R^2 = .99)
GLS-reweighted SASS	vs PSS (R^2 = .99)

The regression lines in figure 1.4, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

$$PSS = (1.03)SASS$$

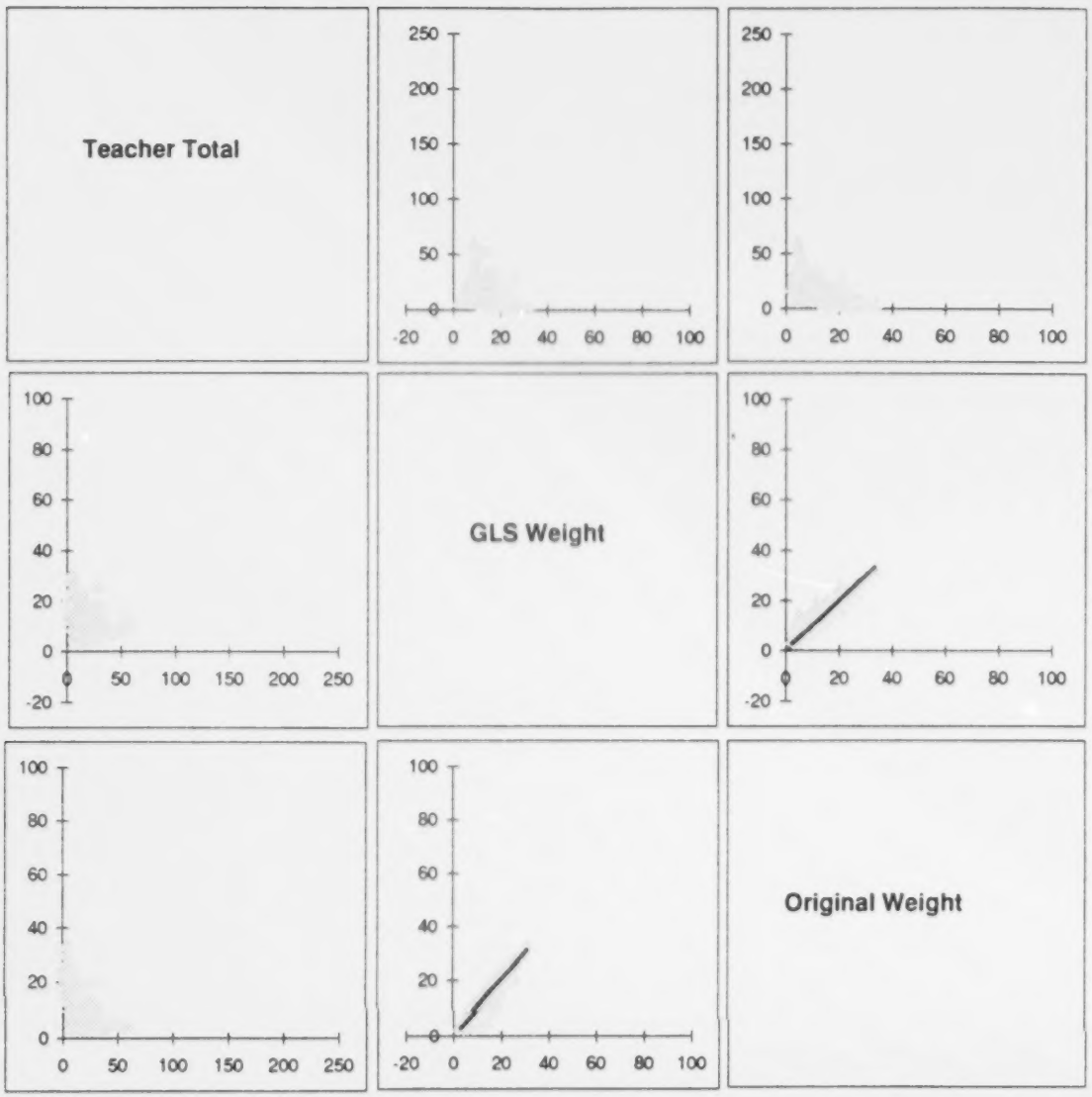
for the GLS-reweighted SASS data and

$$PSS = (1.08)SASS$$

for the original SASS data.

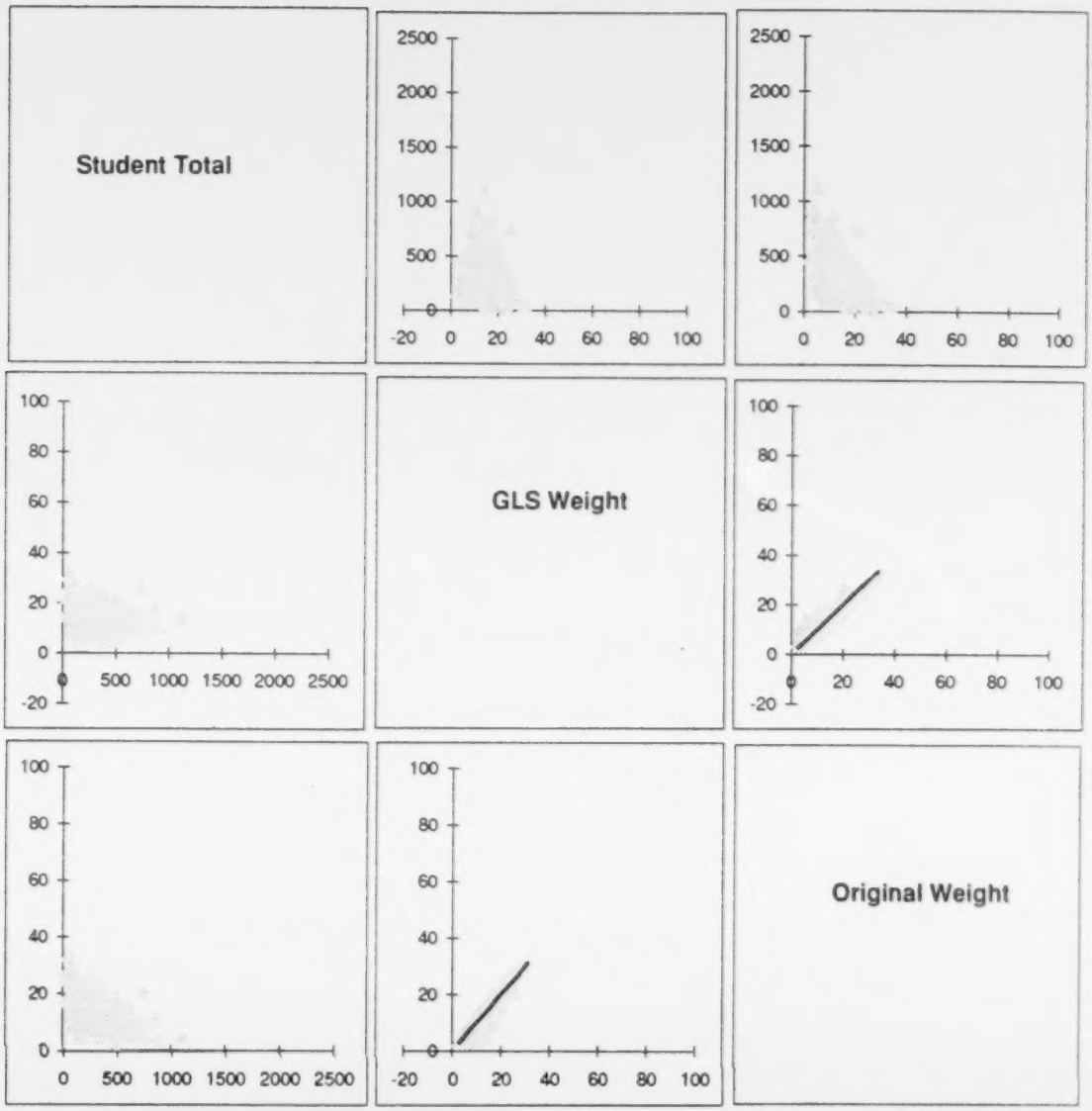
The difference in coefficients (1.03 versus 1.08) shows that the GLS-reweighted SASS data have achieved on average an overall greater closeness to the PSS than did the SASS as originally weighted. Moreover, since the R^2 values are virtually identical, it appears that this improvement in the mean was not at the expense of much roughening in the variance.

Figure 1.2 -- **Catholic Parochial**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 1.3 -- **Catholic Parochial**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



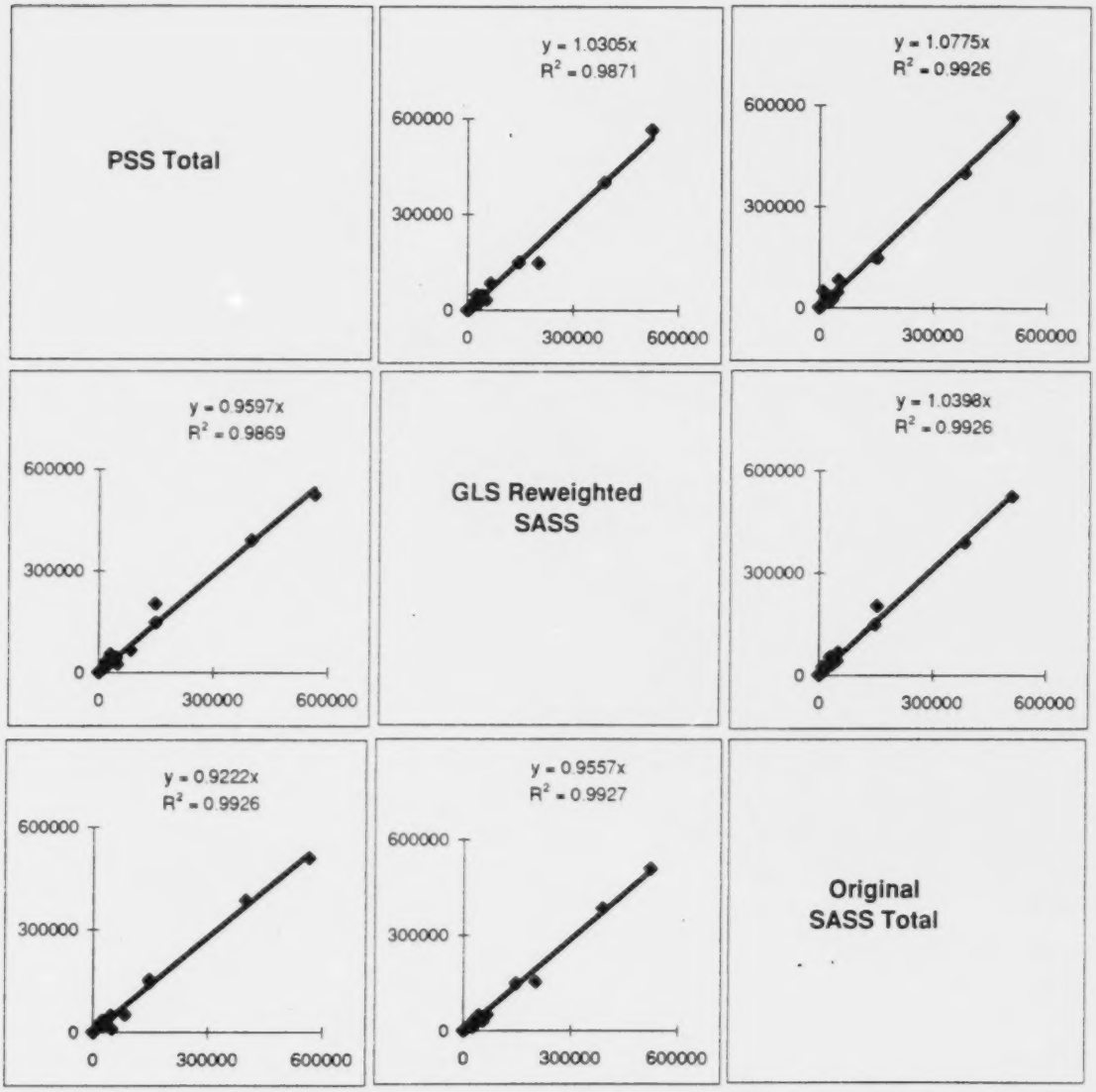
SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Table 1.2 -- **Catholic Parochial**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type: Central City	Community Type: Urban Fringe/ Large Town	Community Type: Rural/ Small Town	Total
Part I - PSS Total					
1-149	School	228	228	442	898
	Teacher	1,461	1,420	2,738	5,619
	Student	23,700	24,164	46,534	94,398
150 - 499	School	2,016	1,441	614	4,071
	Teacher	24,380	17,755	6,985	49,120
	Student	565,742	400,758	149,698	1,116,198
500 - 749	School	252	143	30	425
	Teacher	5,987	3,487	852	10,326
	Student	148,125	83,388	17,490	249,003
750+	School	52	34	4	90
	Teacher	2,163	1,334	179	3,676
	Student	48,751	31,586	3,848	84,185
Total	School	2,548	1,846	1,090	5,484
	Teacher	33,991	23,996	10,754	68,741
	Student	786,318	539,896	217,570	1,543,784
Part II - Original SASS Total					
1 - 149	School	287	351	461	1,099
	Teacher	2,102	2,093	2,945	7,140
	Student	32,951	34,166	48,340	115,457
150 - 499	School	1,832	1,458	611	3,901
	Teacher	21,434	16,715	6,997	45,146
	Student	509,325	384,539	147,483	1,041,347
500 - 749	School	257	93	40	390
	Teacher	6,553	2,104	900	9,557
	Student	153,472	51,643	22,444	227,559
750+	School	12	34	--	46
	Teacher	633	1,164	--	1,797
	Student	10,396	29,532	--	39,928
Total	School	2,388	1,936	1,112	5,436
	Teacher	30,722	22,076	10,842	63,640
	Student	706,144	499,880	218,267	1,424,291
Part III - GLS Reweighted SASS Total					
1 - 149	School	260	318	410	988
	Teacher	1,888	1,895	2,608	6,391
	Student	29,927	31,056	43,047	104,030
150 - 499	School	1,848	1,452	598	3,898
	Teacher	22,000	16,886	6,970	45,856
	Student	524,538	389,064	147,141	1,060,743
500 - 749	School	337	118	53	508
	Teacher	8,855	2,749	1,195	12,799
	Student	202,893	66,376	29,679	298,948
750+	School	30	61	--	91
	Teacher	1,504	2,194	--	3,698
	Student	25,794	54,250	--	80,044
Total	School	2,475	1,949	1,061	5,485
	Teacher	34,247	23,724	10,773	68,744
	Student	783,152	540,746	219,867	1,543,765

SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 1.4 -- **Catholic Parochial**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S.Department of Education, NCES, Private School of School and Staffing Surveys.1990-91, Private School Surveys, 1991-92

3.2 CATHOLIC DIOCESAN TYPOLOGY

The Catholic Diocesan typology represents the second largest type of private school in terms of total students. In the 1991-92 Private School Survey, Catholic Diocesan schools were estimated to number 2,502, or 9.6 percent of the private school total for that year. However, the number of students in such schools (at over 800,000) is a much larger percentage, roughly 15 percent of all private school students.

In table 2.1, a complete comparison is made between SASS and PSS estimates for schools, teachers, and students. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that the schools total is the closest (about four percent below PSS); however, SASS has more teachers and students than are shown in PSS (roughly six percent more of each).

Table 2.1 -- 1991-92 PSS and Original 1990-91 Catholic Diocesan SASS Totals Compared

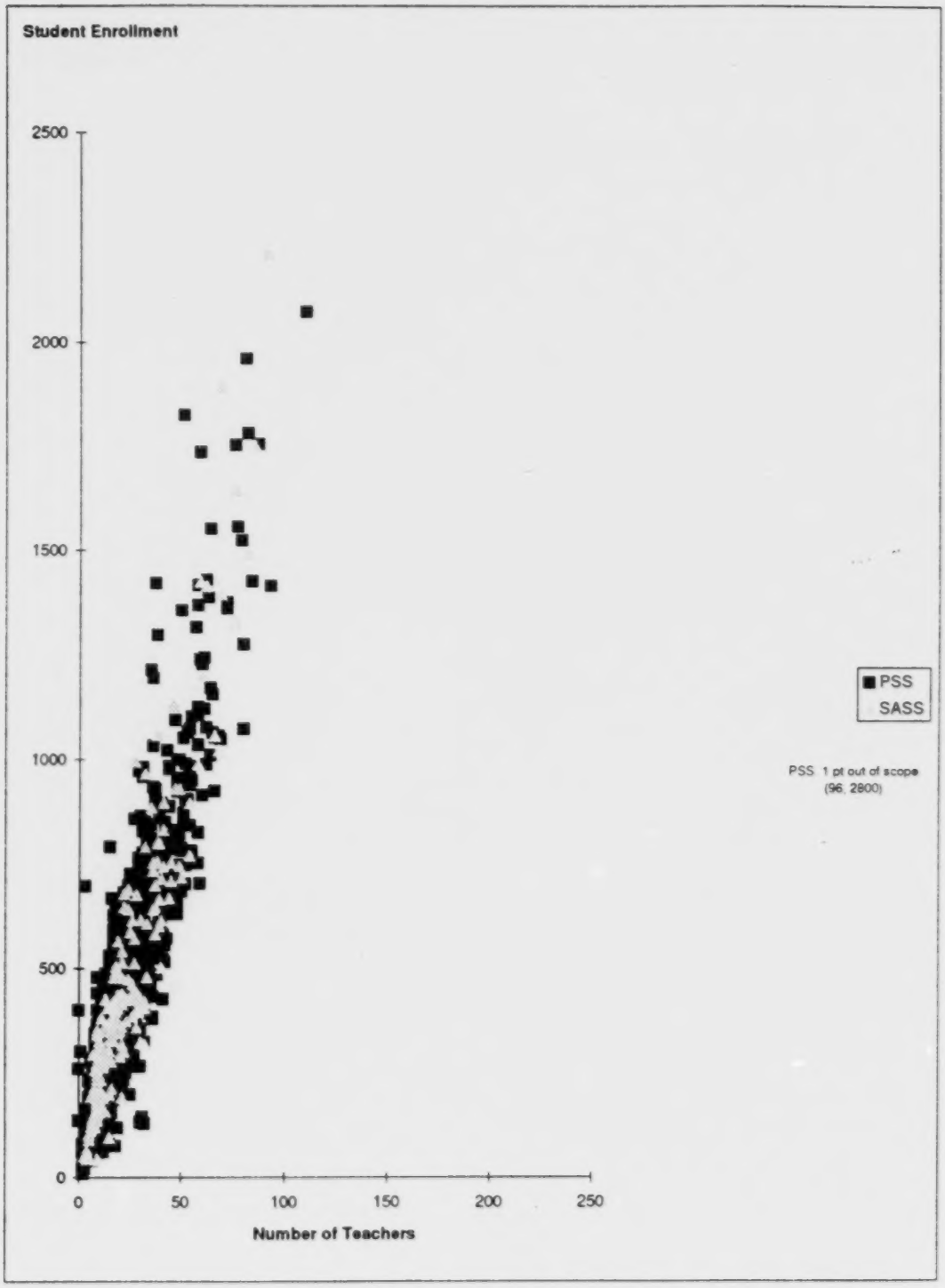
	PSS	SASS
Schools	2,502	2,400
Teachers	38,533	40,686
Students	802,120	851,326

(Note: the numbers here may be different than the numbers in table 2.2 because of rounding.)

To set the stage for the calculations that follow, look at figure 2.1, which provides a scatterplot of student enrollment by number of teachers. The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. The SASS data points lie along the same axis as the PSS data points. In fact, the student/teacher ratios are 20.8 for PSS and 20.9 for SASS.

Another comment about the figure is in order. Notice that there are some very large schools in SASS; possibly this is one of the reasons that SASS totals for teachers and students exceed PSS by so much, even though the total (weighted) number of SASS schools is less. If these surveys were both for the same year, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

Figure 2.1 -- **Catholic Diocesan**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

3.2.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

needed to be solved for the 198 sample cases in the Catholic Diocesan typology. It can be derived from table 2.1 above that $\underline{d}$ is

$$\begin{matrix} 102 \\ -2{,}153 \\ -49{,}206 \end{matrix}$$

The matrix M was obtained by tabulating the 1990-91 SASS file for Catholic Diocesan schools. The values obtained are

198	4,617	92,554
4,617	170,213	3,339,239
92,554	3,339,239	68,880,980

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (2.297, -0.008, -0.003)$ and the modified GLS weights are of the form

$$u_i = w_i + 2.297 - 0.008t_i - 0.003s_i$$

Notice that all of the weights are raised to begin with (by about two). Then there are slight downward adjustments as the number of teachers and students increase. This GLS weight equation thus raises the possibility that some negative weights could occur (as turns out to be true). Finally, while the values for $\underline{\lambda}$ are only shown to three decimal places, the calculations have been developed in double precision.

3.2.2 Operational Characteristics.-- The GLS reweighting does have some undesirable side effects. We will examine several diagnostics to demonstrate this. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that of the original weights, w_i? The ratio of these two quantities turns out to be a lot larger than one (about 1.37) and therefore of some concern. Harm could have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process.

The range of the weights is another measure to examine. This range shows the spread of the weights and any attenuation that may have occurred. Given the

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variance results above, it is not surprising to find that the range of the GLS weights is somewhat longer than for the original weights.

Original	1.4 to 29.8
GLS	-2.1 to 31.6

Why? Both the teacher and student counts in SASS were well above those in PSS (and by roughly the same proportion) while the school totals were lower. So what the modified GLS estimation did was to decrease by a great deal the smaller weights of the larger schools--so much so that five of them were driven negative and an additional one, while remaining positive, became less than one in value. To compensate for the decline in the large schools, the usually larger weights of the smaller schools were raised slightly. Overall, the adjustment increased the variance of the GLS weights and widened their range relative to those originally on the file.

Figures 2.2 and 2.3 illustrate other operating characteristics of the original and GLS weights. Figure 2.2 shows weight declines for schools with more teachers and the corresponding growth in weights for schools with smaller numbers of teachers. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) Incidentally, there is a corresponding decline in the negative simple correlation between the teacher total and the school weight (from about -0.75 to -0.83).

Figure 2.3 shows the same pattern observed with figure 2.2, although this time by enrollment size, where the GLS weight shrinks for schools with more students and goes up for schools with smaller numbers of students. Again, there is a corresponding decline in the negative simple correlation between enrollment and the school weight (from about -0.66 to -0.76).

We will comment on one more panel in figures 2.2 and 2.3, the scatterplot of GLS weights versus original weights. Not surprisingly, a strong relationship exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.2.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Catholic Diocesan Typology are available in table 2.2 and figure 2.4. Table 2.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 2.4 is another version of the data in table 2.2.

On a cell-by-cell basis, the relationship between the two versions of SASS is fairly stable and predictable (R^2 = .96). Each is also closely related to the PSS.

Originally weighted SASS vs PSS (R^2 = .94)
GLS-reweighted SASS vs PSS (R^2 = .97)

The regression lines in figure 2.4, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

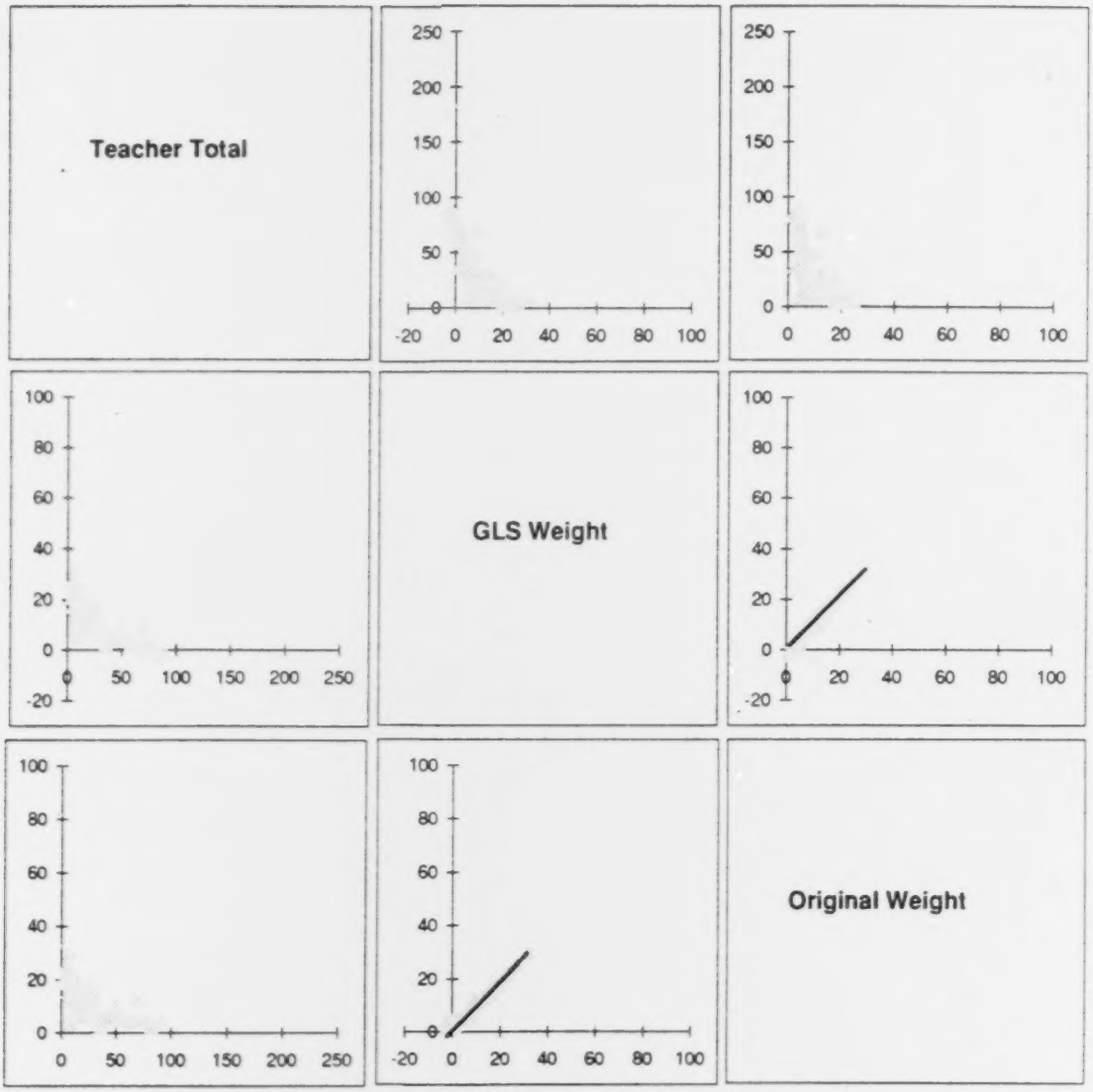
$$PSS = (0.95)SASS$$

for the GLS-reweighted SASS data and

$$PSS = (0.95)SASS$$

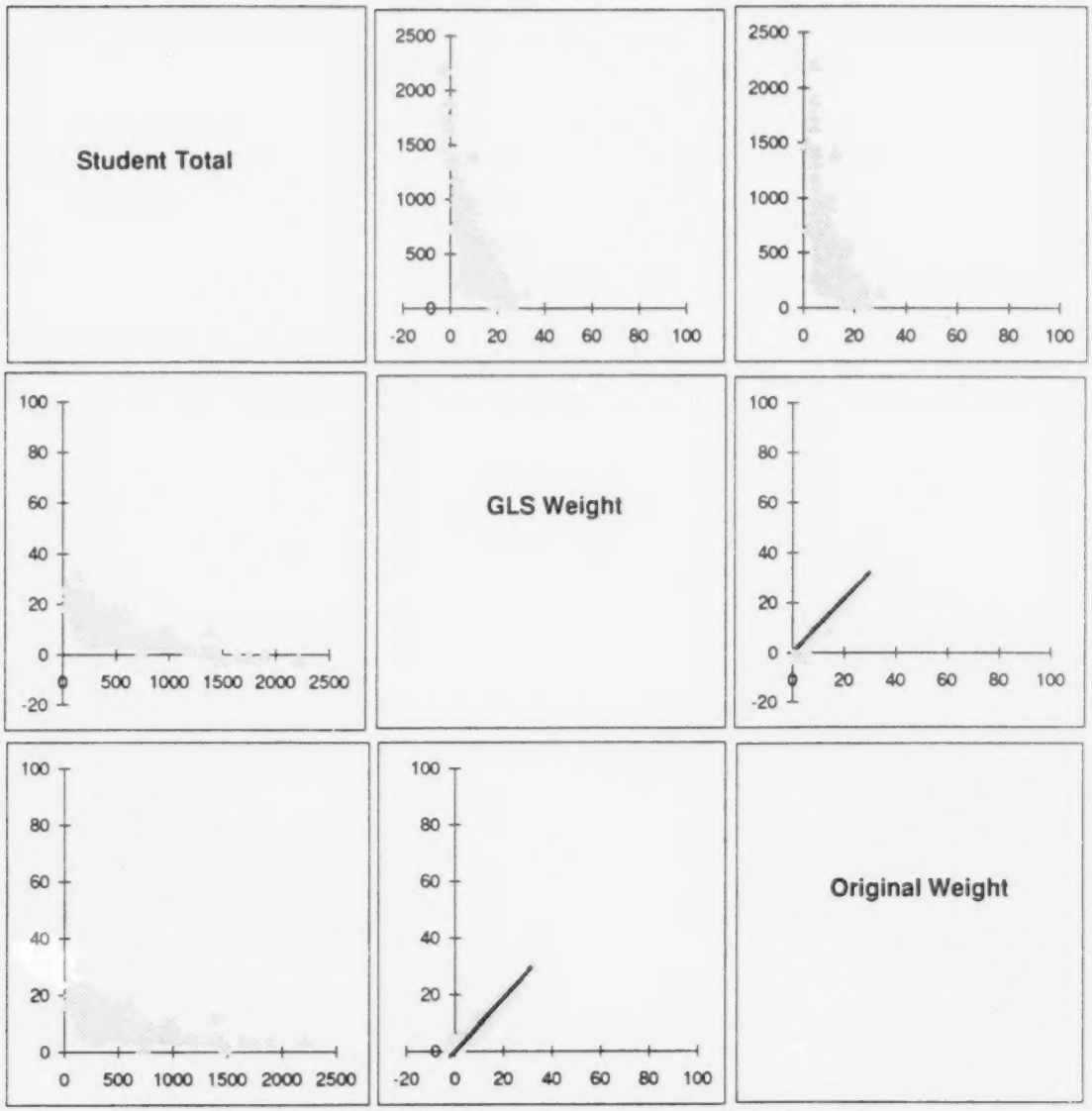
for the original SASS data. While virtually identical, the GLS coefficient is slightly larger (and closer to one). The near agreement in coefficients suggests that, on the average, the GLS adjustment achieved little good. On the other hand, since the R^2 values are virtually identical, too, it appears that not much harm was done either.

Figure 2.2 -- **Catholic Diocesan**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 2.3 -- **Catholic Diocesan**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



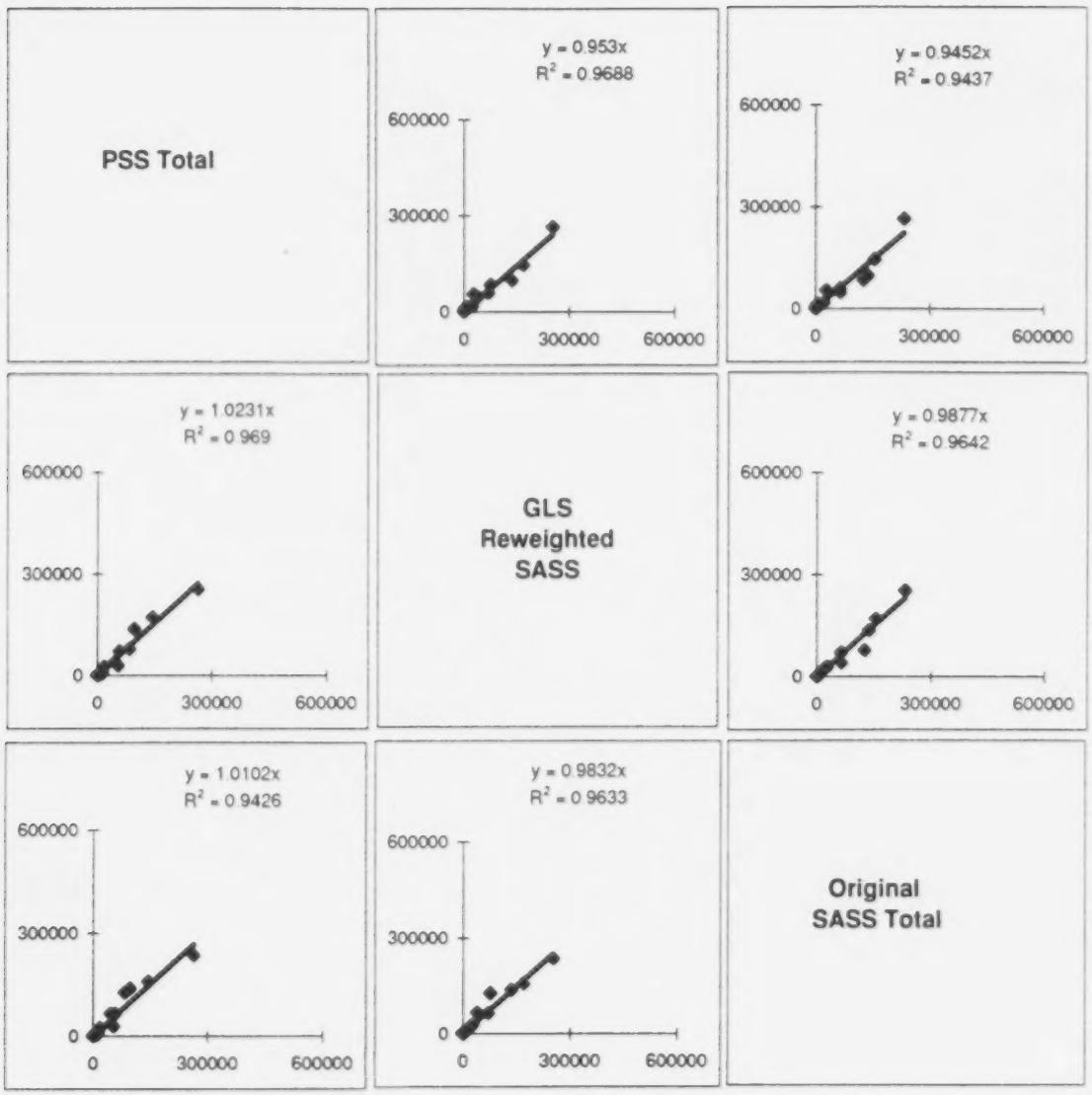
SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Table 2.2 -- **Catholic Diocesan**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type: Central City	Community Type: Urban Fringe/ Large Town	Community Type: Rural/ Small Town	Total
Part I - PSS Total					
1-149	School	113	119	171	403
	Teacher	846	817	1,065	2,728
	Student	12,417	11,840	17,445	41,702
150 - 499	School	939	519	249	1,707
	Teacher	12,340	6,563	3,006	21,909
	Student	264,696	145,745	58,995	469,436
500 - 749	School	162	92	13	267
	Teacher	4,512	2,583	387	7,482
	Student	97,950	54,635	7,402	159,987
750+	School	80	44	1	125
	Teacher	4,119	2,245	51	6,415
	Student	83,715	46,428	852	130,995
Total	School	1,294	774	434	2,502
	Teacher	21,817	12,208	4,509	38,534
	Student	458,778	258,648	84,694	802,120
Part II - Original SASS Total					
1 - 149	School	60	60	221	341
	Teacher	389	598	1,328	2,315
	Student	5,060	7,137	22,542	34,739
150 - 499	School	752	576	281	1,609
	Teacher	11,311	6,971	3,025	21,307
	Student	234,955	157,840	64,517	457,312
500 - 749	School	226	45	--	271
	Teacher	6,651	1,378	--	8,029
	Student	138,358	28,893	--	167,251
750+	School	115	63	--	178
	Teacher	5,938	3,098	--	9,036
	Student	126,778	65,247	--	192,025
Total	School	1,153	744	502	2,399
	Teacher	24,289	12,045	4,353	40,687
	Student	505,151	259,117	87,059	851,327
Part III - GLS Reweighted SASS Total					
1 - 149	School	66	66	242	374
	Teacher	429	653	1,453	2,535
	Student	5,532	7,773	24,637	37,942
150 - 499	School	815	622	307	1,744
	Teacher	12,289	7,508	3,311	23,108
	Student	253,719	169,762	70,432	493,913
500 - 749	School	224	44	--	268
	Teacher	6,520	1,333	--	7,853
	Student	136,301	28,060	--	164,361
750+	School	76	40	--	116
	Teacher	3,586	1,451	--	5,037
	Student	75,517	30,389	--	105,906
Total	School	1,181	772	549	2,502
	Teacher	22,824	10,945	4,764	38,533
	Student	471,069	235,984	95,069	802,122

SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 2.4 -- **Catholic Diocesan**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

3.3 CATHOLIC PRIVATE TYPOLOGY

The Catholic Private typology is a fairly small component of the private school universe. In the 1991-92 Private School Survey, there were estimated to be just 901 Catholic Private schools, or 3.5 percent of the private school total for that year.

In table 3.1, a complete comparison is made between SASS and PSS estimates for schools, teachers, and students.. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that the schools total is already very close (within one percent); SASS has slightly fewer teachers (also by less than one percent) but about three percent more students than are shown in PSS.

Table 3.1 -- 1991-92 PSS and Original 1990-91 Catholic Private SASS Totals Compared

	PSS	SASS
Schools	901	894
Teachers	22,520	22,340
Students	354,040	365,367

(Note: The numbers here may be different than the numbers in table 3.2 because of rounding.)

To set the stage for the calculations that follow, look at figure 3.1, which provides a scatterplot of student enrollment by number of teachers. The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. As can be seen, the SASS data points lie within the parameters of the PSS data points, and along the same axis. In fact, the student/teacher ratios are 16.4 for PSS and 15.7 for SASS.

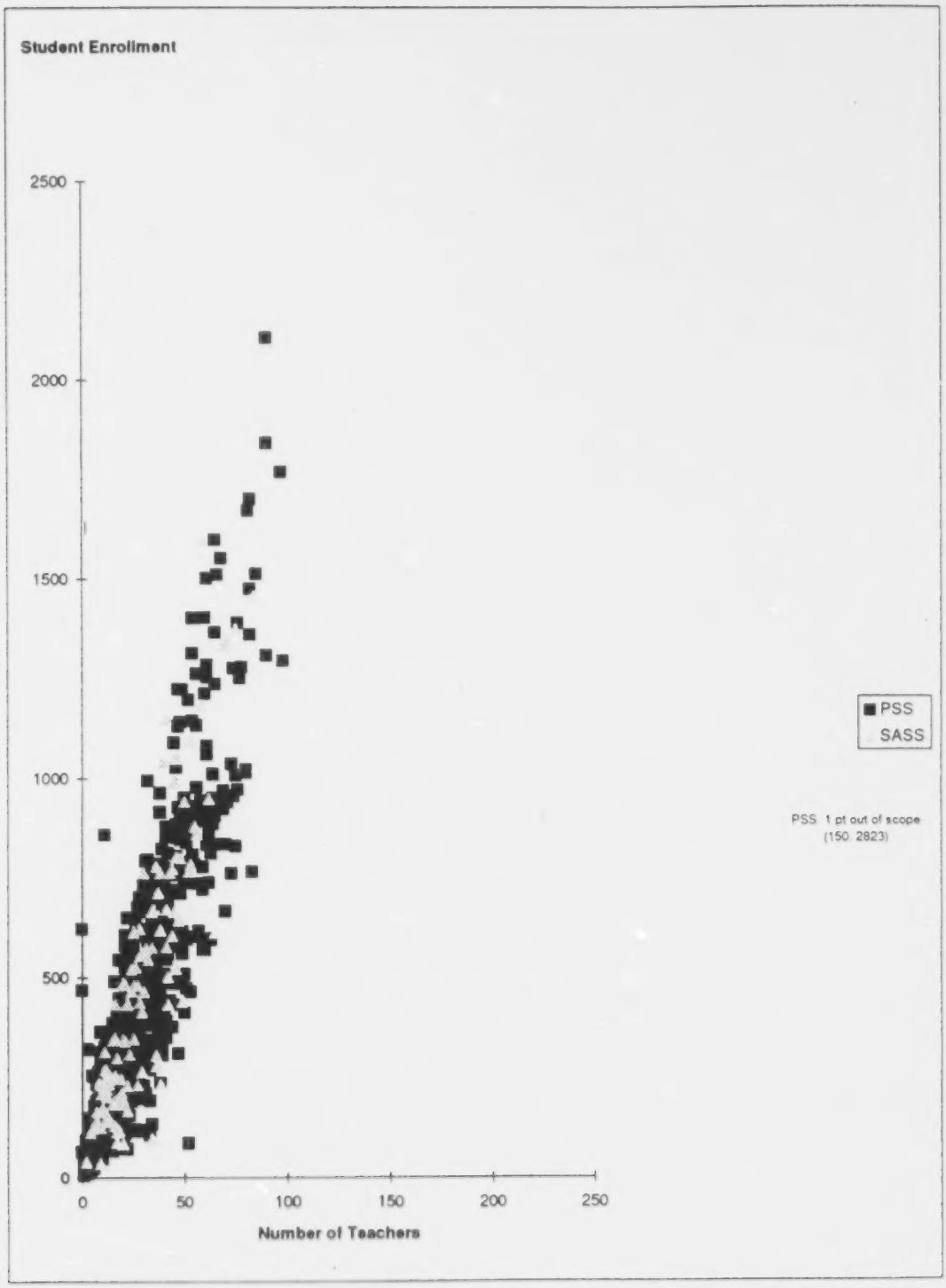
If these surveys were both for the same year, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

3.3.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

needed to be solved for the 112 SASS sample cases in the Catholic Private Typology.

Figure 3.1 -- **Catholic Private**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

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It can be derived from table 3.1 above that $\underline{d}$ is

$$\begin{matrix} 7 \\ 180 \\ -11{,}327 \end{matrix}$$

The matrix M was obtained by tabulating the 1990-91 SASS file for Catholic Private schools. The values obtained are

112	3,305	54,651
3,305	133,975	2,226,822
54,651	2,226,822	40,123,861

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (0.041, 0.077, -0.005)$ and the modified GLS weights are of the form

$$u_i = w_i + 0.041 + 0.077t_i - 0.005s_i$$

Notice that all the original weights are increased on an overall basis but only very slightly (by less than 0.05); then, depending on the teacher and student counts in the sampled school, they are lowered (or raised), again to some apparently small degree, given the size of the coefficients. Looking just at the equation, concerns about negative weights exist; however, as will be seen below, these did not materialize. Finally, while the values for $\underline{\lambda}$ are only shown to three decimal places, the calculations have been carried out in double precision.

3.3.2 Operational Characteristics.-- The GLS reweighting seems to have worked well. We will look at several diagnostics to justify this observation. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that for the original weights, w_i? The ratio of these two quantities turns out to be almost one (1.05)--an encouraging outcome. It suggests minimal or no harm may have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process.

The range of the weights is another measure worth calculating. This range shows the spread of the weights and any attenuation that may have occurred. Given the variance results above, it is not surprising to find that the range of the GLS weights is actually shorter than for the original weights, albeit not by much.

Original	1.1 to 23.6
GLS	1.1 to 23.1

Why? The teacher totals in SASS were on the low side; conversely, the SASS student counts were above those in PSS while the school totals were fairly close.

What the modified GLS estimation did was to adjust--sometimes upward, sometimes downward--the weights of the larger schools (without changing the range of the weights on the low end). To keep the school totals close to equal, it lowered, on balance, the usually larger weights of the smaller schools (enough to lower the high end of the range slightly). Overall, this reduced the variance of the GLS weights and narrowed their range, relative to those originally on the file. This would seem to be a good outcome.

Figures 3.2 and 3.3 illustrate other operating characteristics of the original and GLS weights. Figure 3.2 shows the slight weight increases for schools with more teachers and the corresponding decline in weights for schools with smaller numbers of teachers. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) Incidentally, there is a corresponding tiny reduction in the absolute value of the simple correlation between the teacher total and the school weight (from about -0.47 to -0.46).

Figure 3.3 shows a somewhat different pattern, where the GLS weight declines ever so slightly for schools with more students and increases for schools with smaller numbers of students. There is a corresponding decline in the already negative simple correlation between enrollment and the school weight (from about -0.43 to -0.51).

One more panel in figures 3.2 and 3.3 is worth mentioning, the scatterplot of GLS weights versus original weights. Not surprisingly, a strong relationship exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.3.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Catholic Private Typology are available in table 3.2 and figure 3.4. Table 3.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 3.4 is another version of the data in table 3.2.

On a cell-by-cell basis, the relationship between the two versions of SASS is fairly stable and predictable ($R^2 = .99$). Each is also closely related to the PSS.

Originally weighted SASS	vs PSS ($R^2 = .997$)
GLS-reweighted SASS	vs PSS ($R^2 = .989$)

The regression lines in figure 3.5, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

$$PSS = (0.98)SASS$$

for the GLS-reweighted SASS data and

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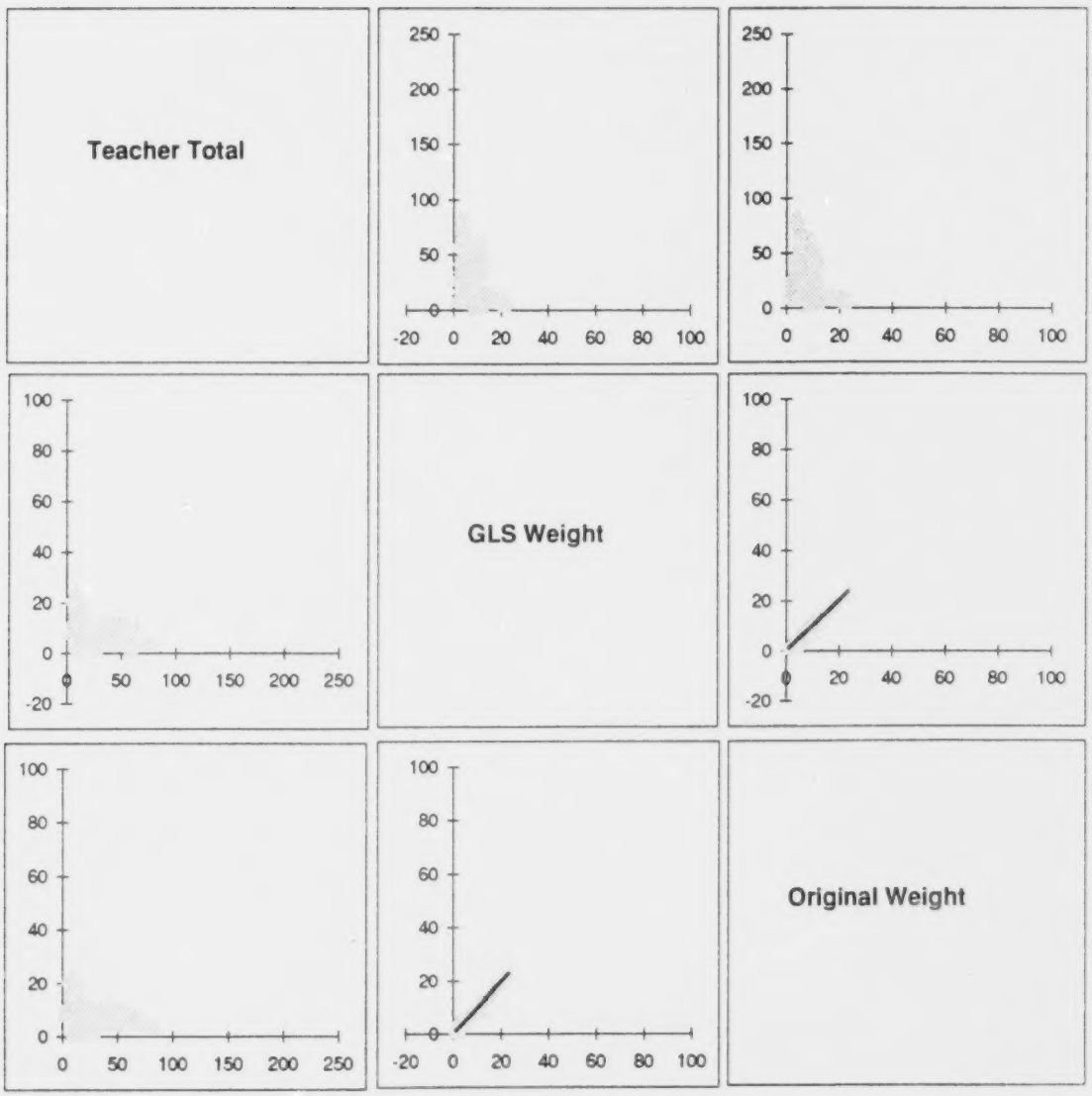
$$PSS = (0.94)SASS$$

for the original SASS data.

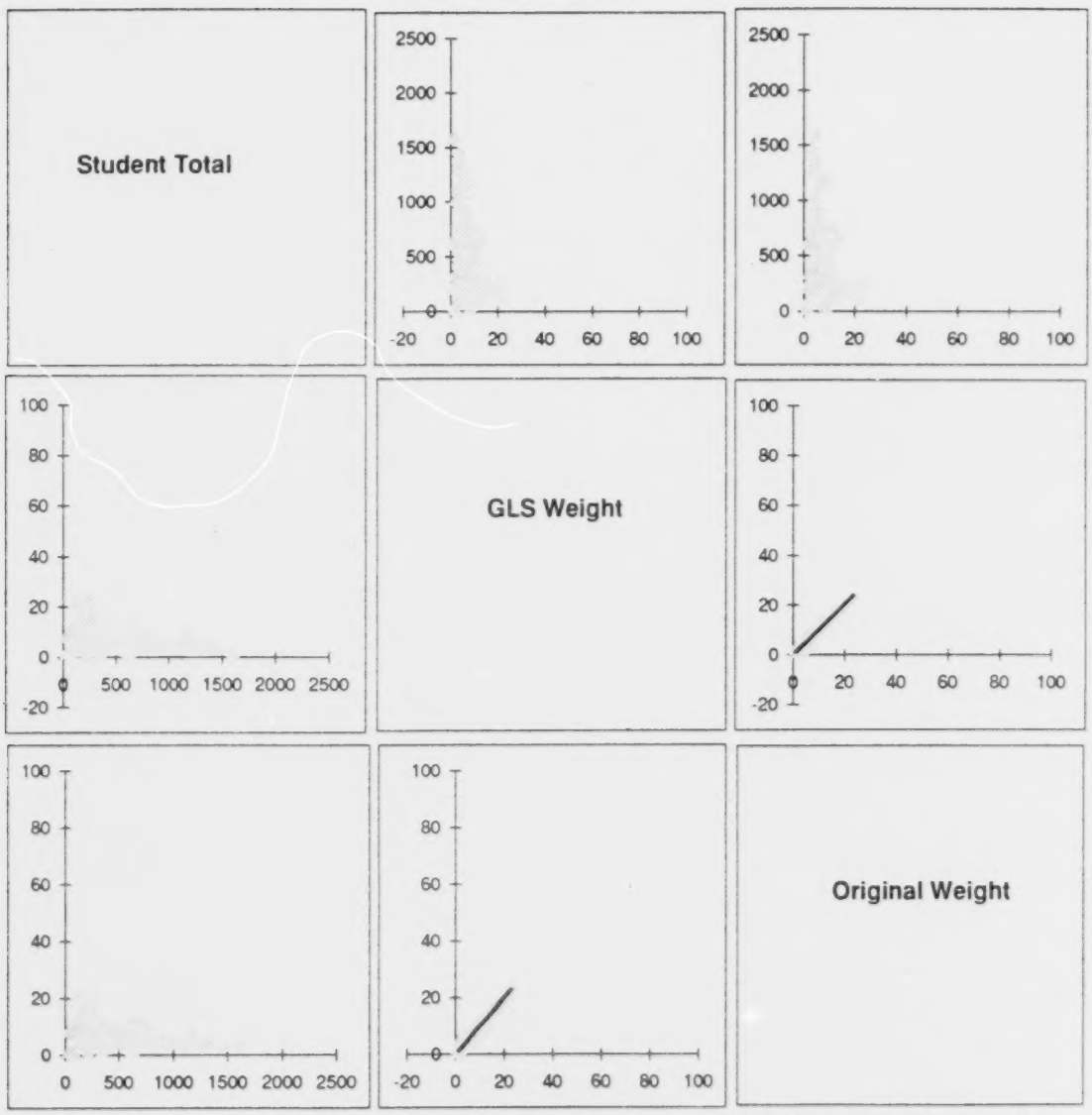
The difference in coefficients (0.98 vs 0.94) shows that the GLS-reweighted SASS data have achieved on average an overall greater closeness to the PSS than did SASS as originally weighted. Moreover, since the R^2 values are virtually identical, it appears that this improvement in the mean was not at the expense of much roughening in the variance.

Figure 3.2 -- **Catholic Private**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 3.3 -- **Catholic Private**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



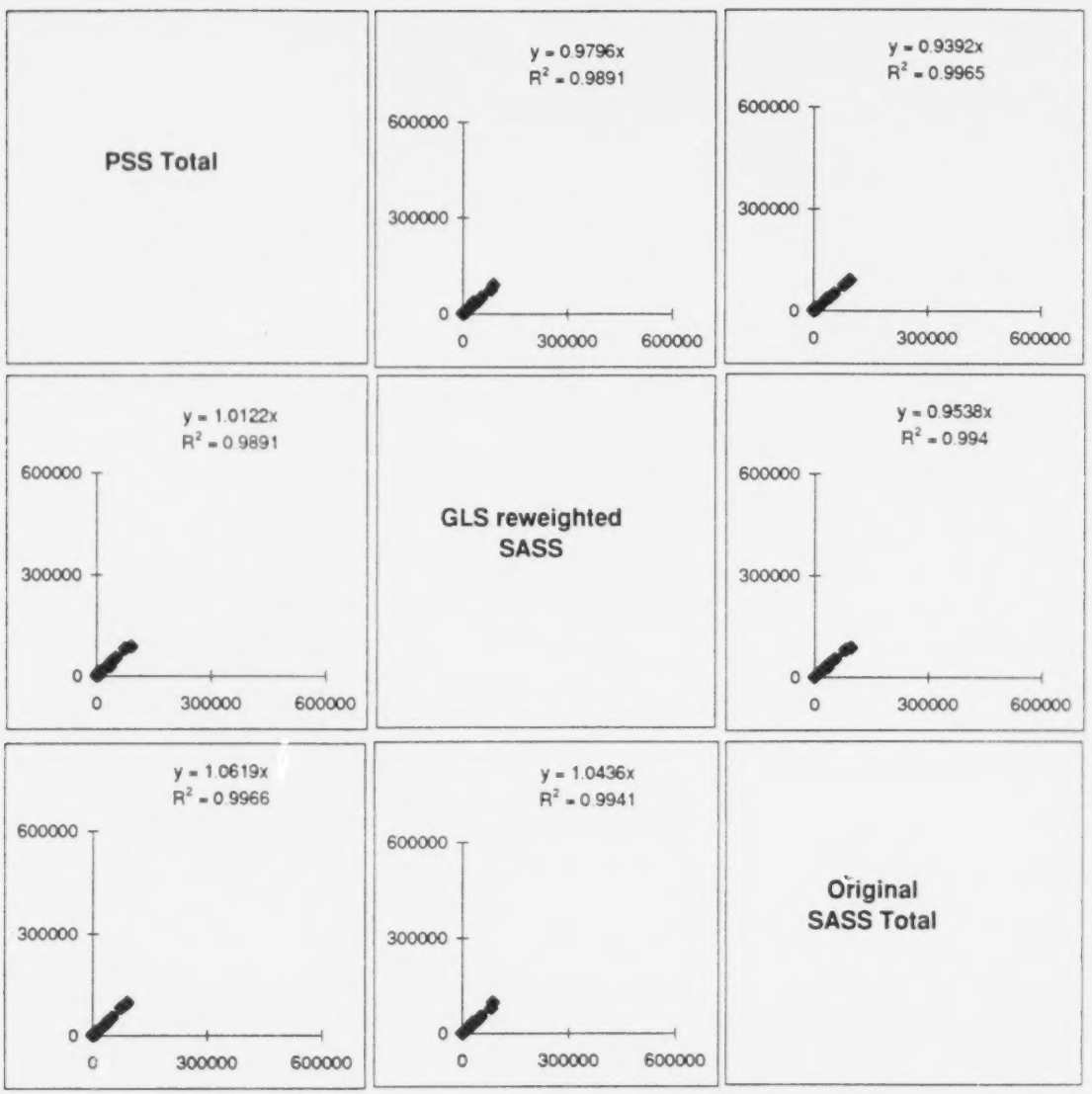
SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys,1990-91, Private School Surveys, 1991-92

Table 3.2 -- **Catholic Private**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type: Central City	Community Type: Urban Fringe/ Large Town	Community Type: Rural/ Small Town	Total
Part I - PSS Total					
1-149	School	90	60	69	219
	Teacher	652	636	537	1,825
	Student	6,971	5,176	5,231	17,378
150 - 499	School	243	136	45	424
	Teacher	4,791	2,793	805	8,389
	Student	74,904	39,194	11,865	125,963
500 - 749	School	83	48	5	136
	Teacher	2,959	1,838	175	4,972
	Student	51,154	28,495	2,673	82,322
750+	School	86	34	2	122
	Teacher	5,314	1,962	57	7,333
	Student	90,869	35,697	1,811	128,377
Total	School	502	278	121	901
	Teacher	13,716	7,229	1,574	22,519
	Student	223,898	108,562	21,580	354,040
Part II - Original SASS Total					
1 - 149	School	18	79	31	128
	Teacher	166	1,171	196	1,533
	Student	2,538	8,968	3,172	14,678
150 - 499	School	279	159	58	496
	Teacher	4,646	3,160	868	8,674
	Student	81,144	41,904	13,370	136,418
500 - 749	School	89	50	--	139
	Teacher	3,104	2,077	--	5,181
	Student	54,013	28,312	--	82,325
750+	School	100	33	--	133
	Teacher	5,250	1,702	--	6,952
	Student	97,417	34,529	--	131,946
Total	School	486	321	89	896
	Teacher	13,166	8,110	1,064	22,340
	Student	235,112	113,713	16,542	365,367
Part III - GLS Reweighted SASS Total					
1 - 149	School	18	87	31	136
	Teacher	168	1,332	200	1,700
	Student	2,562	9,670	3,207	15,439
150 - 499	School	280	166	59	505
	Teacher	4,731	3,401	949	9,081
	Student	81,123	43,770	13,777	138,670
500 - 749	School	88	54	--	142
	Teacher	3,124	2,297	--	5,421
	Student	53,491	30,536	--	84,027
750+	School	91	27	--	118
	Teacher	4,876	1,442	--	6,318
	Student	87,305	28,607	--	115,912
Total	School	477	334	90	901
	Teacher	12,899	8,472	1,149	22,520
	Student	224,481	112,583	16,984	354,048

SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 3.4 -- **Catholic Private**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

3.4 CONSERVATIVE CHRISTIAN TYPOLOGY

The Conservative Christian Typology represents a large part of the private school universe. In the 1991-92 Private School Survey, this typology was estimated to have 4,291 schools, or 16.5 percent of the private school total for that year.

Table 4.1 -- 1991-92 PSS and Original 1990-91 Conservative Christian SASS Totals Compared

	PSS	SASS
Schools	4,291	4,045
Teachers	37,534	34,486
Students	651,746	591,981

(Note: The numbers here may be different than the numbers in table 4.2 because of rounding.)

In table 4.1, a complete comparison is made between SASS and PSS estimates for schools, teachers, and students. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that the schools total is off by about six percent (being too low); the weighted SASS estimates for teachers and students are even lower (by eight percent to nine percent less respectively) than in PSS.

To set the stage for the calculations that follow, look at figure 4.1, which provides a scatterplot of student enrollment by number of teachers. The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. As can be seen, the SASS data points lie within the parameters of the PSS data points, and along the same axis. In fact, the student/teacher ratios are 17.4 for PSS and 17.2 for SASS.

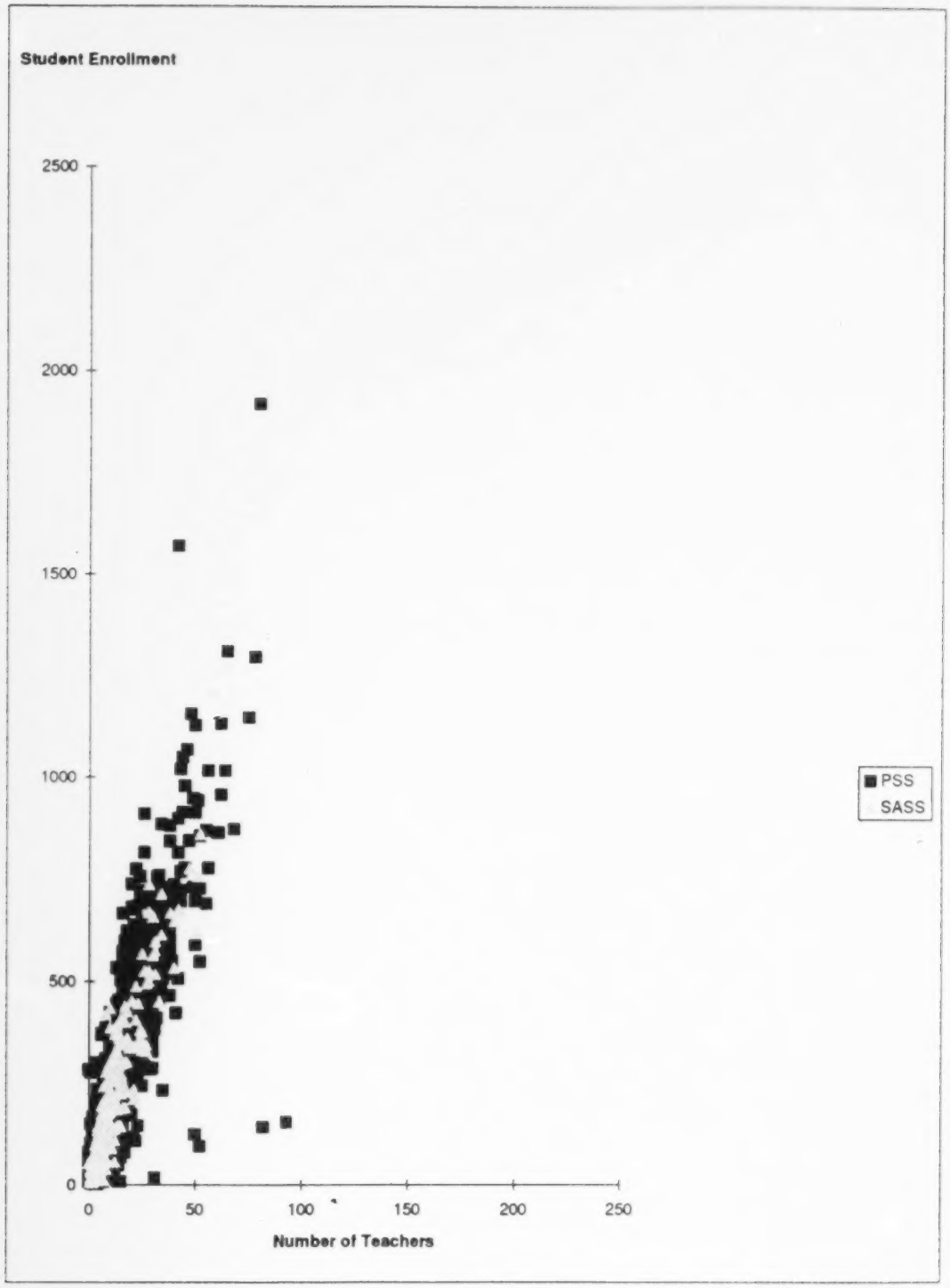
These surveys are not for the same year but, if they were, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

3.4.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

needed to be solved for the 292 SASS sample cases in the Conservative Christian Typology.

Figure 4.1 -- **Conservative Christian**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

It can be derived from table 4.1 above that $\underline{d}$ is

246

3,048

59,765

The matrix M was obtained by tabulating the 1990-91 SASS file for the Conservative Christian schools. The values are

292	3,207	57,895
3,207	67,131	1,189,684
57,895	1,189,684	22,446,787

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (0.695, -0.053, 0.004)$ and the modified GLS weights are of the form

$$u_i = w_i + 0.695 - 0.053t_i + 0.004s_i$$

Notice that the original weights are initially increased by about 0.7. A moderately large downward adjustment is then made depending on the number of teachers that the SASS sample case has. Finally, a slight upward correction is made based on the number of students in the SASS school. This setup causes concerns about negative weights, but they do not occur, as will be discussed below.

3.4.2 Operational Characteristics.-- The GLS reweighting seems to have worked well for this typology. To justify this observation, we will look at several diagnostics. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that for the original weights, w_i? The ratio of these two quantities turns out to be virtually one (i.e., 0.99), an encouraging outcome. It suggests minimal or no harm may have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process.

The range of the weights is another measure worth calculating. This range shows the spread of the weights and any attenuation that may have occurred. Given the variance results above, it is not surprising to find that the range of the GLS weights is shorter than for the original weights, albeit not by much.

Original	1.0 to 93.4
GLS	1.6 to 94.1

Both the teacher and student counts in SASS were below those in PSS (and by roughly the same proportion); the school totals were lower, too, but less so. What the modified GLS estimation did in this situation was to increase the weights of all the schools, although on balance the larger schools were increased slightly more. Overall,

this kept the variance of the GLS weights virtually unchanged and shifted their range, even narrowing it, but not appreciably over that originally on the file.

Figures 4.2 and 4.3 illustrate other operating characteristics of the original and GLS weights. Figure 4.2 shows weight increases for schools with more teachers and the corresponding decline in weights for schools with smaller numbers of teachers. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) Incidentally, there is a corresponding decline in the absolute value of the simple correlation between the teacher total and the school weight (from about -0.25 to -0.24).

Figure 4.3 shows the same pattern observed earlier--this time by enrollment size--where the GLS weight increases for schools with more students and declines for schools with smaller numbers of students. Again, there is a corresponding slight decline in the (absolute) simple correlation between enrollment and the school weight (from about -0.28 to -0.27).

We will comment on one more panel in figures 4.2 and 4.3, the scatterplot of GLS weights versus original weights. Not surprisingly, a strong relationship exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.4.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Conservative Christian Typology are available in table 4.2 and figure 4.4. Table 4.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 4.4 is another version of the data in table 4.2.

On a cell-by-cell basis, the relationship between the two versions of SASS is stable and predictable ($R^2 = .999$). Each is also closely related to the PSS.

Originally weighted SASS	vs PSS ($R^2 = .97$)
GLS-reweighted SASS	vs PSS ($R^2 = .97$)

The regression lines in figure 4.4, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

$$PSS = (0.99)SASS$$

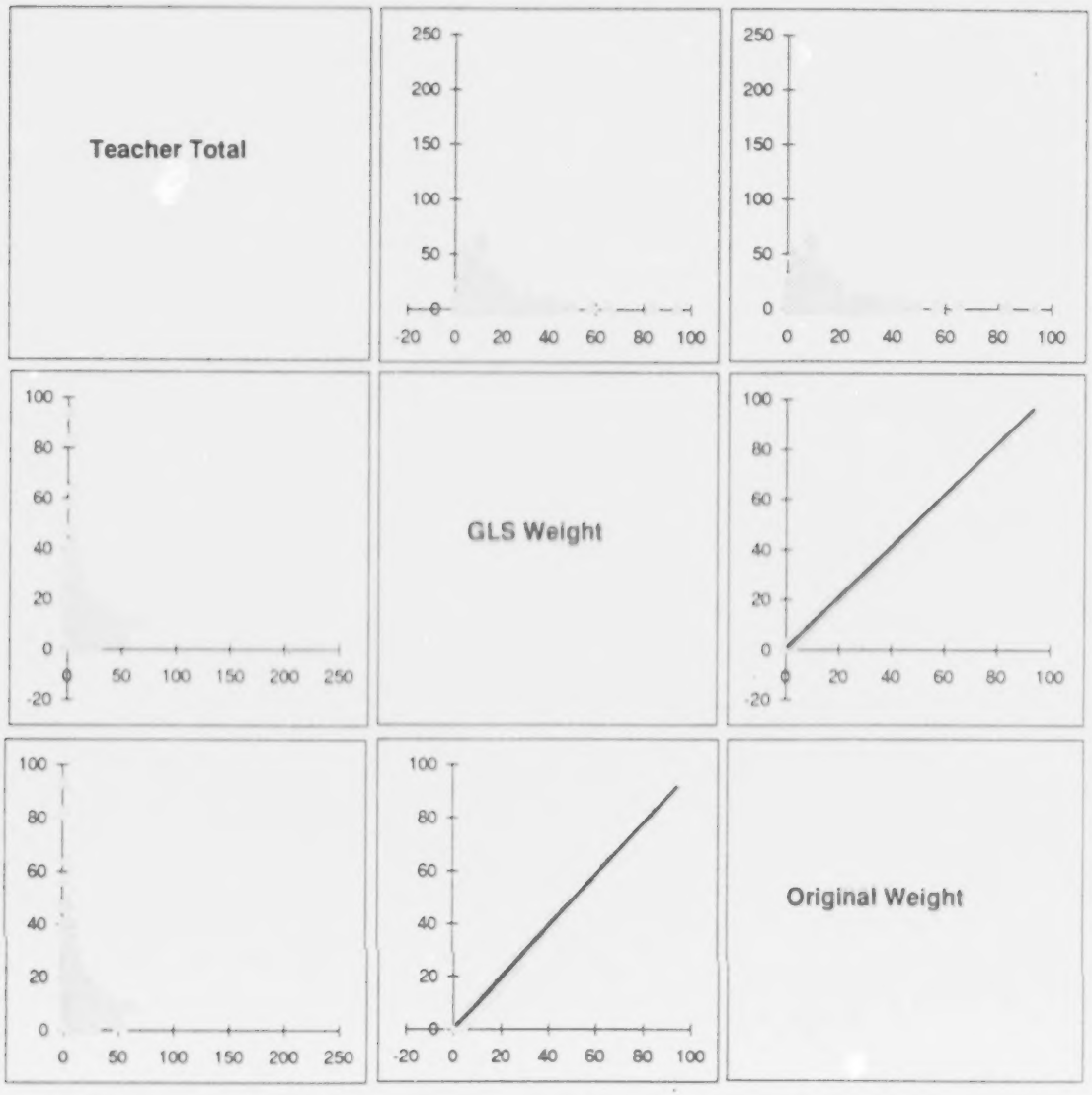
for the GLS-reweighted SASS data and

$$PSS = (1.09)SASS$$

for the original SASS data.

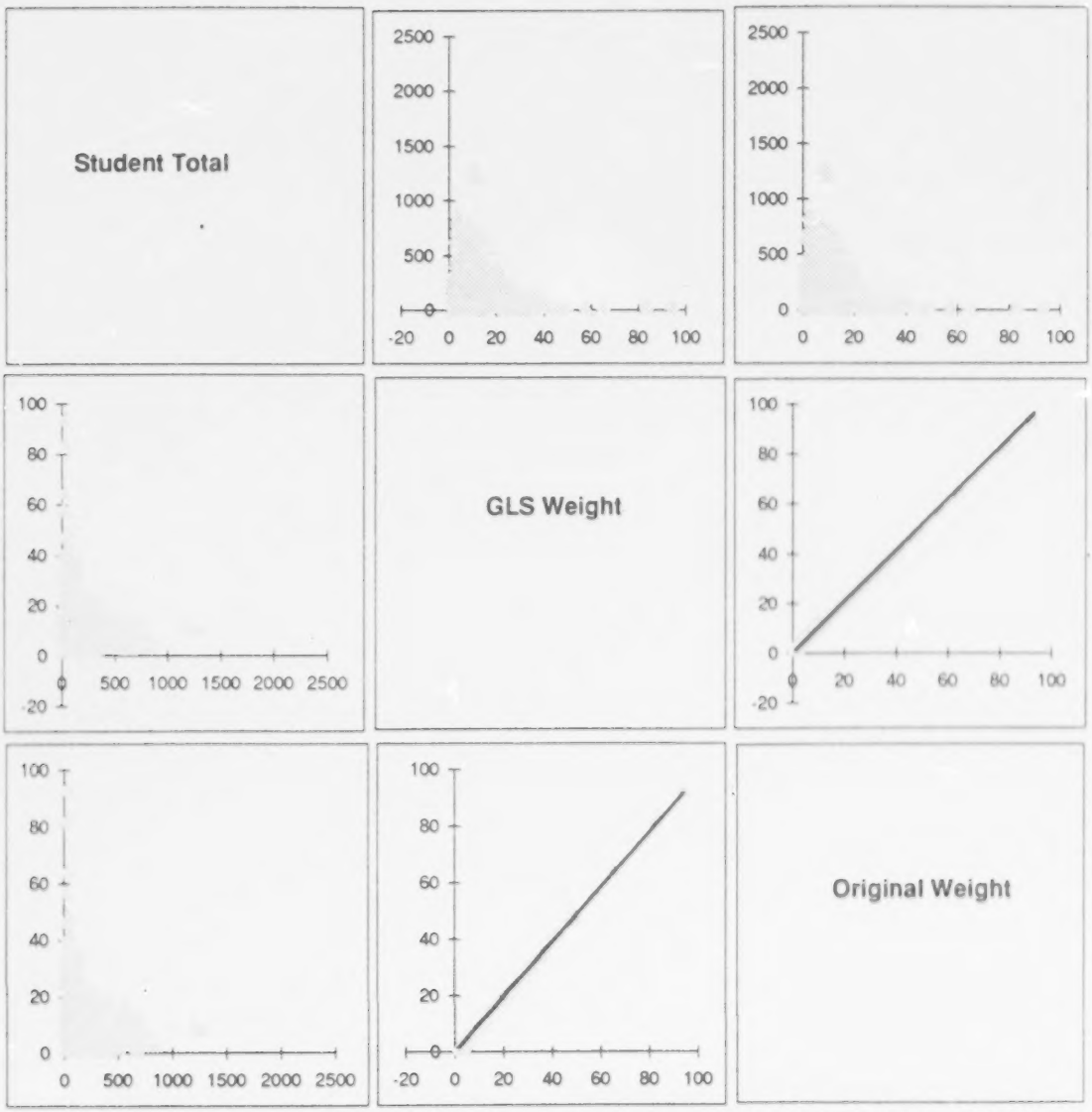
The difference in coefficients (0.99 vs 1.09) shows that the GLS-reweighted SASS data have achieved on average an overall greater closeness to the PSS than did SASS as originally weighted. Moreover, since the R^2 values are virtually identical, it appears that this improvement in the mean was not at the expense of much roughening in the variance.

Figure 4.2 -- **Conservative Christian**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 4.3 -- **Conservative Christian**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

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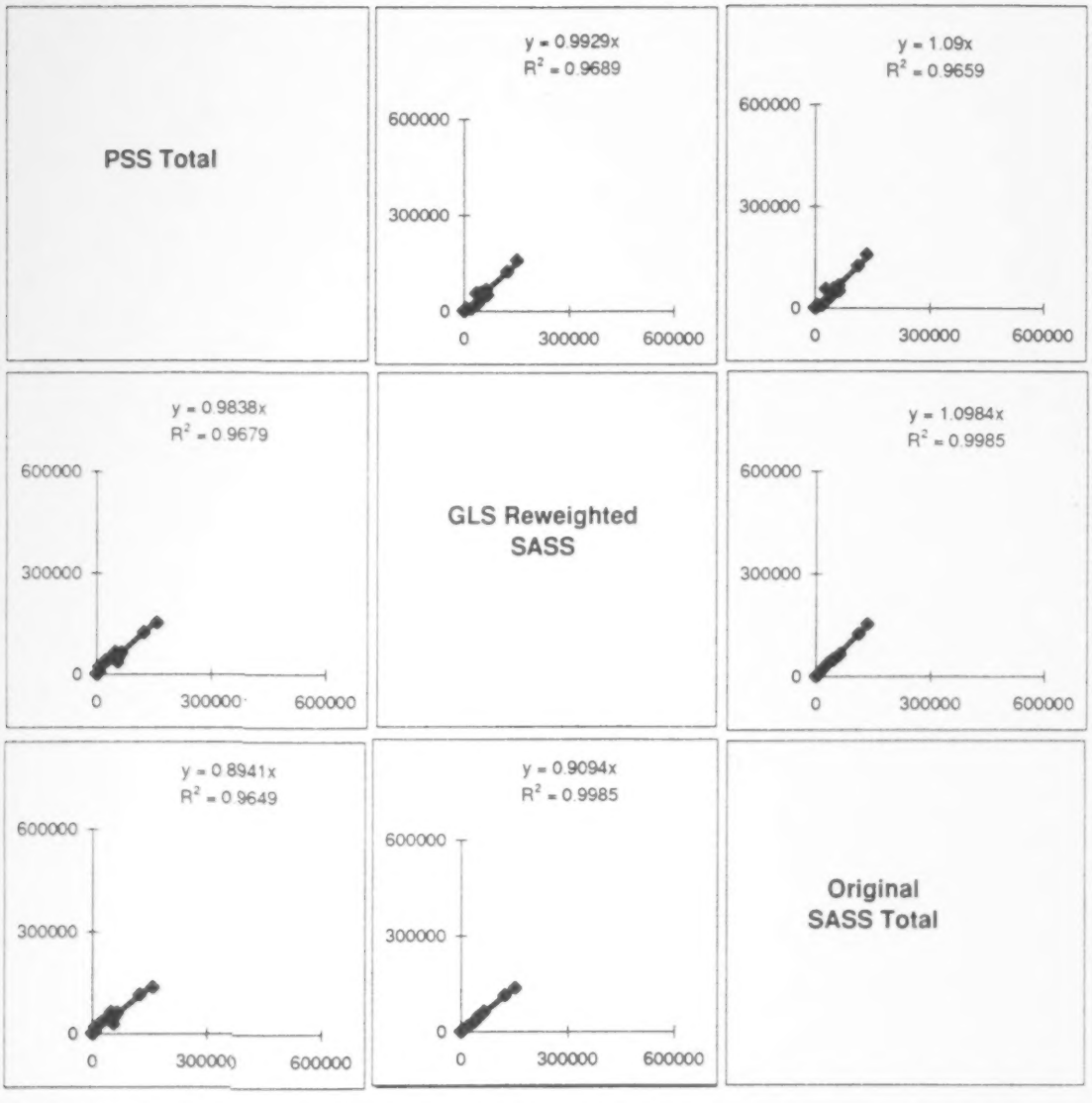
Table 4.2 -- **Conservative Christian**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type			Total
		Central City	Urban Fringe/ Large Town	Rural/ Small Town	
Part I - PSS Total					
1-149	School	783	767	1,266	2,816
	Teacher	4,110	3,738	5,207	13,055
	Student	57,793	50,125	66,151	174,069
150 - 499	School	600	466	192	1,258
	Teacher	8,160	6,464	2,394	17,018
	Student	159,150	123,952	45,392	328,494
500 - 749	School	92	63	12	167
	Teacher	2,857	1,828	356	5,041
	Student	55,547	37,633	7,592	100,772
750+	School	25	23	1	49
	Teacher	1,264	1,063	93	2,420
	Student	24,712	22,502	1,197	48,411
Total	School	1,500	1,319	1,471	4,290
	Teacher	16,391	13,093	8,050	37,534
	Student	297,202	234,212	120,332	651,746
Part II - Original SASS Total					
1 - 149	School	560	904	1,287	2,751
	Teacher	2,883	4,437	5,322	12,642
	Student	47,749	53,017	61,454	172,220
150 - 499	School	485	414	213	1,112
	Teacher	6,505	5,970	2,381	14,856
	Student	136,057	113,349	45,632	295,038
500 - 749	School	46	78	28	152
	Teacher	1,570	2,722	961	5,253
	Student	29,135	44,410	18,521	92,066
750+	School	31	--	--	31
	Teacher	1,735	--	--	1,735
	Student	32,658	--	--	32,658
Total	School	1,122	1,396	1,528	4,046
	Teacher	12,693	13,129	8,664	34,486
	Student	245,599	220,776	125,607	591,982
Part III - GLS Reweighted SASS Total					
1 - 149	School	595	940	1,328	2,863
	Teacher	3,059	4,626	5,508	13,193
	Student	50,775	66,036	63,939	180,750
150 - 499	School	538	452	227	1,217
	Teacher	7,195	6,482	2,541	16,218
	Student	151,894	124,049	48,760	324,703
500 - 749	School	56	86	32	174
	Teacher	1,884	3,012	1,100	5,996
	Student	35,312	49,432	21,563	106,307
750+	School	38	--	--	38
	Teacher	2,128	--	--	2,128
	Student	39,976	--	--	39,976
Total	School	1,227	1,478	1,587	4,292
	Teacher	14,266	14,120	9,149	37,535
	Student	277,957	239,517	134,262	651,736

SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 4.4 -- **Conservative Christian**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

3.5 OTHER AFFILIATED TYPOLOGY

The Other Affiliated Typology represents one of the larger types of private schools. In the 1991-92 Private School Survey, there were an estimated 3,950 such schools, or 15.2 percent of the private school total for that year.

Table 5.1 - 1991-92 PSS and Original 1990-91 Other Affiliated SASS Totals Compared

	PSS	SASS
Schools	3,950	4,262
Teachers	38,136	39,660
Students	683,725	711,260

Note: The numbers here may be different than the numbers in table 5.2 because of rounding.

In table 5.1, a complete comparison is made between SASS and PSS estimates for schools, teachers, and students. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that the schools total for SASS is quite a bit higher (about eight percent); the SASS-weighted counts for teachers and students are also higher than those in PSS but less so (only about four percent more in both cases).

To set the stage for the calculations that follow, look at figure 5.1, which provides a scatterplot of student enrollment by number of teachers. The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. As can be seen, the SASS data points lie within the parameters of the PSS data points, and along the same axis. In fact, the student/teacher ratios are identical (at 17.9) for PSS and SASS.

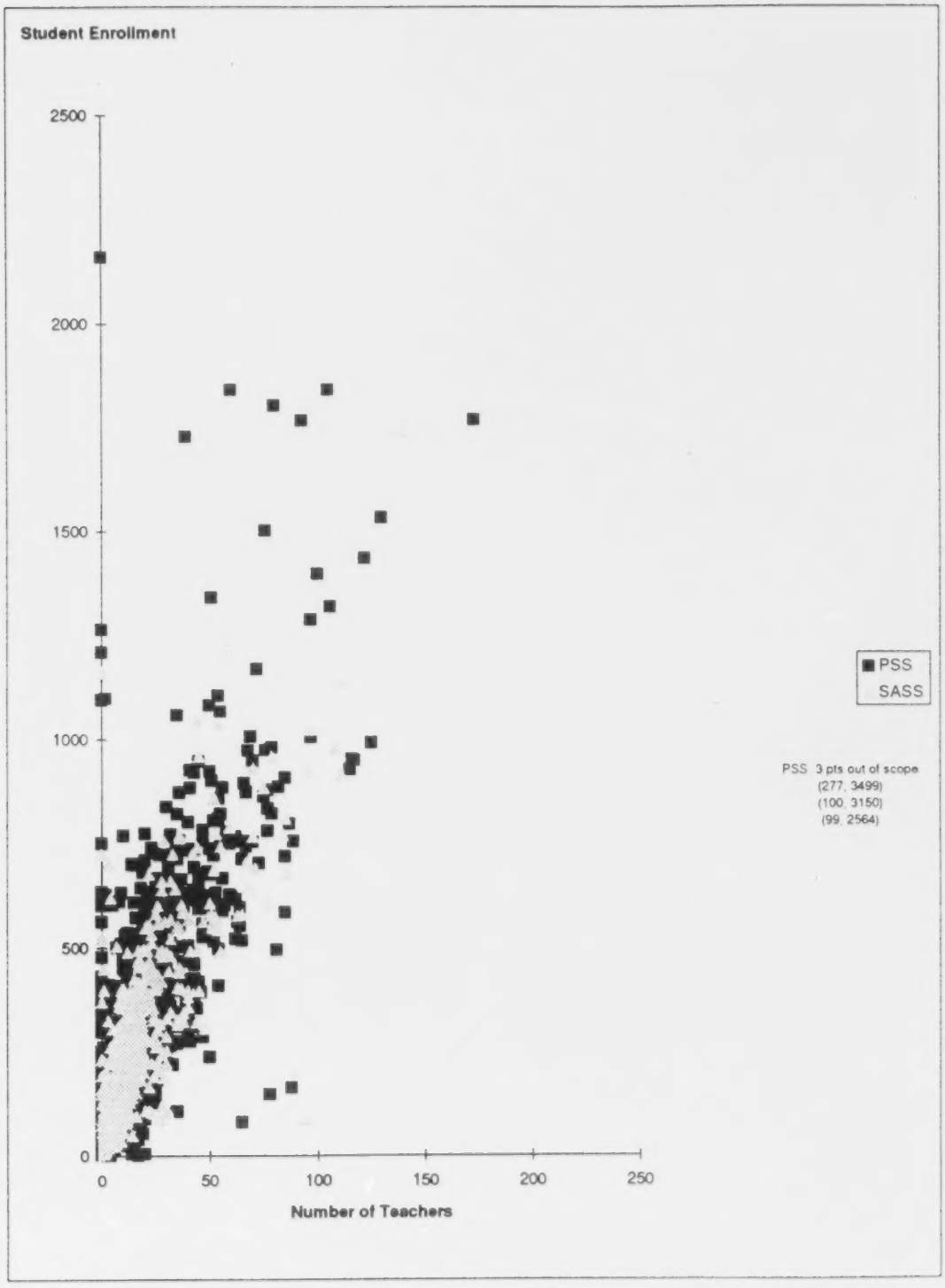
If these surveys were both for the same year, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

3.5.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

needed to be solved for the 815 sample cases in the Other Affiliated typology.

Figure 5.1 -- **Other Affiliated**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys 1990-91, Private School Surveys, 1991-92

It can be derived from table 5.1 above that $\underline{d}$ is

-312

-1,524

-27,535

The matrix M was obtained by tabulating the 1990-91 SASS file for Other Affiliated schools. The values are

815	10,758	181,722
10,758	365,664	4,578,010
181,722	4,578,010	74,211,982

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (-0.663, -0.002, 0.001)$ and the modified GLS weights are of the form

$$u_i = w_i - 0.663 - 0.002t_i + 0.001s_i$$

Notice that all the original weights are lowered (by about 0.7); depending on the teacher and student counts in the sampled school, they may be increased again or lowered further (usually they would not be lowered further since the teacher and student coefficients are of the same order and, in virtually all schools, the student totals are many times larger). These additional school-by-school adjustments do not appear to be too drastic--given that the coefficients on the teacher and student counts are so small. Looking just at the equation, we were concerned that negative weights would arise, but they did not, as will be seen below. (Concerns about weights that are less than one are another matter). Finally, while the values for $\underline{\lambda}$ are only shown to three decimal places, the calculations have all been carried out in double precision.

3.5.2 Operational Characteristics.-- We will examine several diagnostics to see how well the GLS weighting worked. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that for the original weights, w_i? The ratio of these two quantities turns out to be almost exactly equal to one--an encouraging outcome. It suggests minimal or no harm may have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process.

The range of the weights is another measure worth calculating. This range shows the spread of the weights and any attenuation that may have occurred. Given the variance results above, it is not surprising to find that the width of the GLS weight range is almost the same as that for the original weights. A serious difficulty exists

with the new weights, however, in that a great many of them (about 200, or one-fourth of the SASS sample for this typology) are less than one, as seen below.

Original	1.0 to 47.7
GLS	0.4 to 47.2

Both the teacher and student counts in SASS were above those in PSS (and by roughly the same proportion). On the other hand, the SASS school totals, while higher as well, were a lot closer. So what the modified GLS estimation did was to decrease the weights of all SASS schools; the weights of the larger schools, those with already small weights, were lowered somewhat more than the usually larger weights of the smaller schools. Since there were many schools with original weights at one or just above it, the resulting GLS weights were made what may be considered unacceptably small.

Figures 5.2 and 5.3 illustrate other operating characteristics of the original and GLS weights. Figure 5.2 shows the overall downward shift in the GLS weights. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) Incidentally, there is a corresponding decline in the absolute value of the simple correlation between the teacher total and the school weight (from about -0.19 to -0.16).

Figure 5.3 also shows the same pattern observed earlier--this time by enrollment size--where the GLS weights decline for all schools no matter what their numbers of students. Again, there is a corresponding decline in the absolute value of the simple correlation between enrollment and the school weight (from about -0.22 to -0.19).

We will comment on the more panel in figures 5.2 and 5.3, the scatterplot of GLS weights versus original weights. Not surprisingly, a strong relationship exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.5.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Other Affiliated Typology are available in table 5.2 and figure 5.4. Table 5.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS, with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 5.4 is another version of the data in table 5.2.

On a cell-by-cell basis, the relationship between the two versions of SASS is fairly stable and predictable ($R^2 = .997$). Each is also closely related to the PSS.

Originally weighted SASS	vs PSS ($R^2 = .94$)
GLS-reweighted SASS	vs PSS ($R^2 = .95$)

The regression lines in figure 5.4, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

$$PSS = (0.97)SASS$$

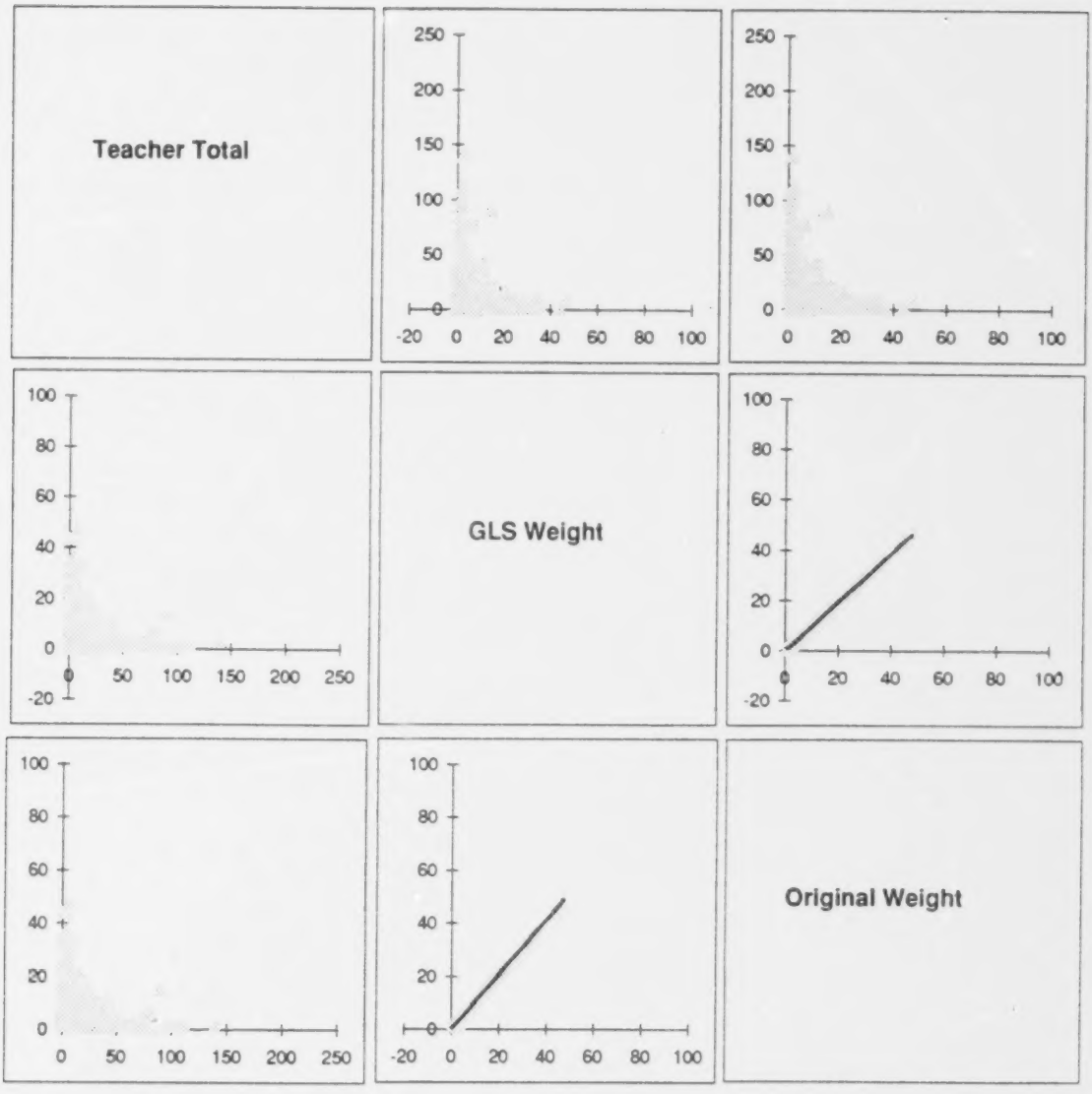
for the GLS-reweighted SASS data and

$$PSS = (0.90)SASS$$

for the original SASS data.

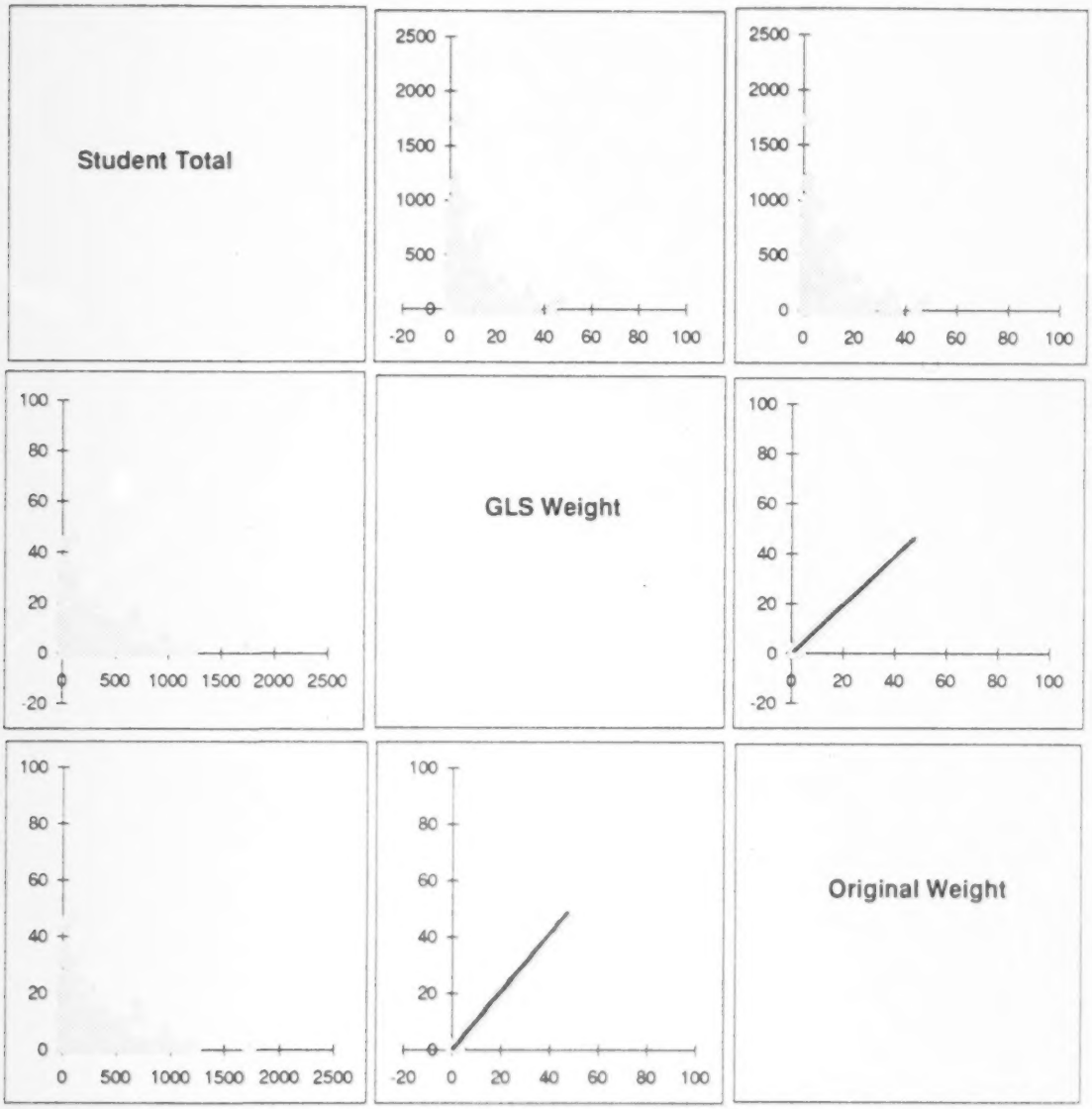
The difference in coefficients (0.97 versus 0.90) shows that the GLS-reweighted SASS data have achieved on average an overall greater closeness to the PSS that did SASS as originally weighted. Moreover, since the R^2 values are virtually identical, it appears that this improvement in the mean was not at the expense of much roughening in the variance.

Figure 5.2 -- **Other Affiliated**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 5.3 -- **Other Affiliated**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



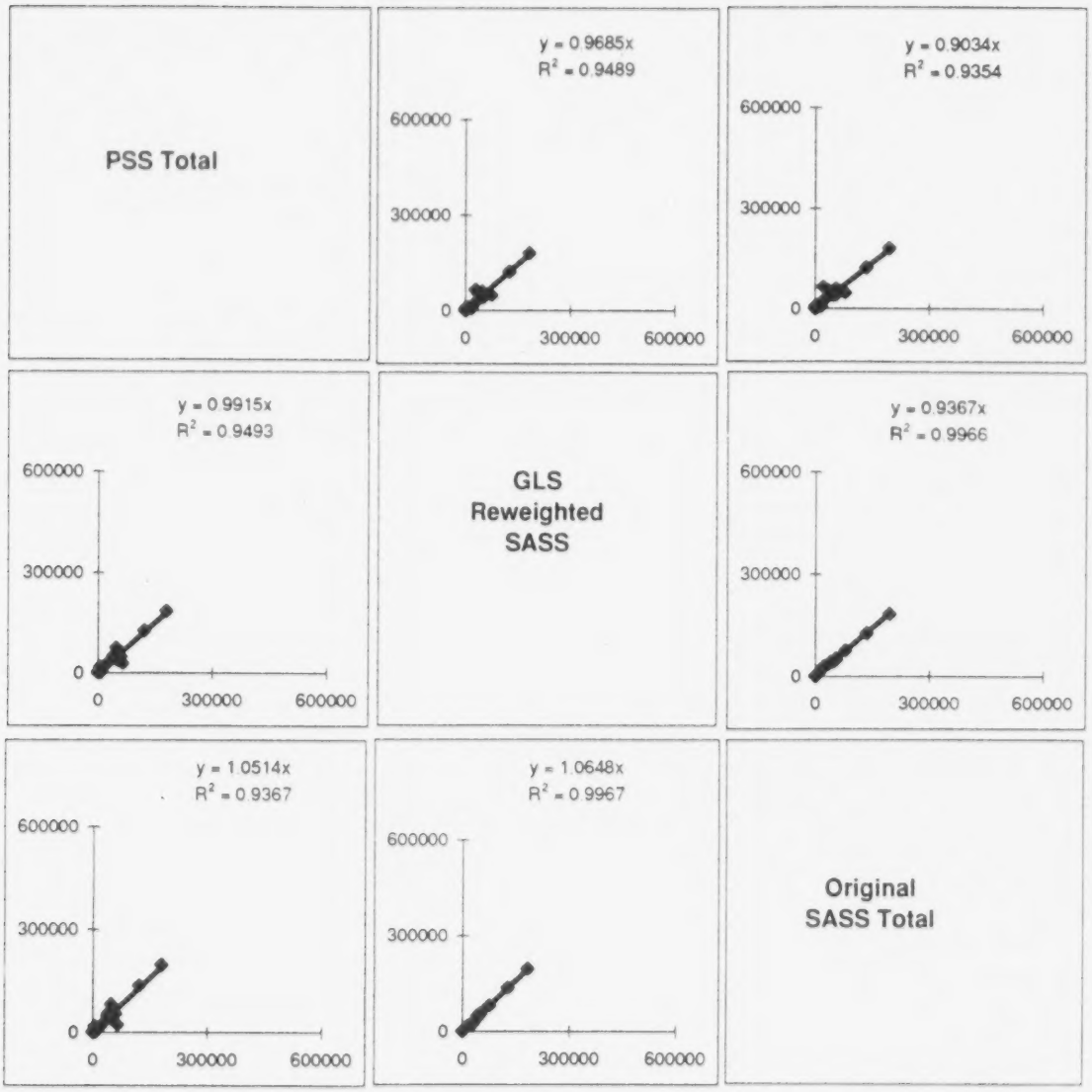
SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Table 5.2 -- **Other Affiliated**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type: Central City	Community Type: Urban Fringe/ Large Town	Community Type: Rural/ Small Town	Total
Part I - PSS Total					
1-149	School	833	582	922	2,337
	Teacher	3,826	2,584	2,801	9,211
	Student	59,772	39,741	41,220	140,733
150 - 499	School	690	477	196	1,363
	Teacher	9,265	6,152	2,679	18,096
	Student	179,986	121,960	47,788	349,734
500 - 749	School	87	67	11	165
	Teacher	2,933	2,002	318	5,253
	Student	52,280	40,310	6,379	98,969
750+	School	58	22	5	85
	Teacher	3,693	1,432	451	5,576
	Student	64,136	22,882	7,271	94,289
Total	School	1,668	1,148	1,134	3,950
	Teacher	19,717	12,170	6,249	38,136
	Student	356,174	224,893	102,658	683,725
Part II - Original SASS Total					
1 - 149	School	764	657	1,015	2,436
	Teacher	3,670	2,944	3,462	10,076
	Student	55,468	47,992	55,763	159,223
150 - 499	School	766	511	349	1,626
	Teacher	9,320	6,535	5,323	21,178
	Student	196,197	136,018	80,853	413,068
500 - 749	School	59	64	29	152
	Teacher	1,859	2,194	1,202	5,255
	Student	35,656	41,110	17,287	94,053
750+	School	25	22	2	49
	Teacher	1,770	1,330	52	3,152
	Student	22,783	20,779	1,353	44,915
Total	School	1,614	1,254	1,395	4,263
	Teacher	16,619	13,003	10,039	39,661
	Student	310,104	245,899	155,256	711,259
Part III - GLS Reweighted SASS Total					
1 - 149	School	687	589	953	2,229
	Teacher	3,221	2,565	3,192	8,978
	Student	49,194	42,463	51,668	143,325
150 - 499	School	708	469	326	1,503
	Teacher	8,630	6,014	4,988	19,632
	Student	182,790	126,208	75,597	384,595
500 - 749	School	61	66	30	157
	Teacher	1,927	2,279	1,225	5,431
	Student	37,148	42,451	17,753	97,352
750+	School	31	28	2	61
	Teacher	2,299	1,733	61	4,093
	Student	29,222	27,598	1,586	58,406
Total	School	1,487	1,152	1,311	3,950
	Teacher	16,077	12,591	9,466	38,134
	Student	298,354	238,720	146,604	683,678

SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 5.4 -- **Other Affiliated**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys 1990-91, Private School Surveys, 1991-92

3.6 OTHER UNAFFILIATED TYPOLOGY

The Other Unaffiliated Typology is among the larger private school types. In the 1991-92 Private School Survey, there were estimated to be 3,519 such schools, or 13.5 percent of the private school total for that year.

Table 6.1 -- 1991-92 PSS and Original 1990-91 Other Unaffiliated SASS Totals Compared

	PSS	SASS
Schools	3,519	3,169
Teachers	24,868	22,723
Students	426,658	310,189

(Note: The numbers here may be different than the numbers in table 6.2 because of rounding.)

In table 6.1, SASS and PSS estimates are compared for schools, teachers, and students. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that the SASS school totals are well under those in the PSS (by almost ten percent); similarly, SASS has many fewer teachers (about nine percent less). However, the biggest shortage in SASS relative to PSS lies in the number of students, where SASS is lower by over 27 percent.

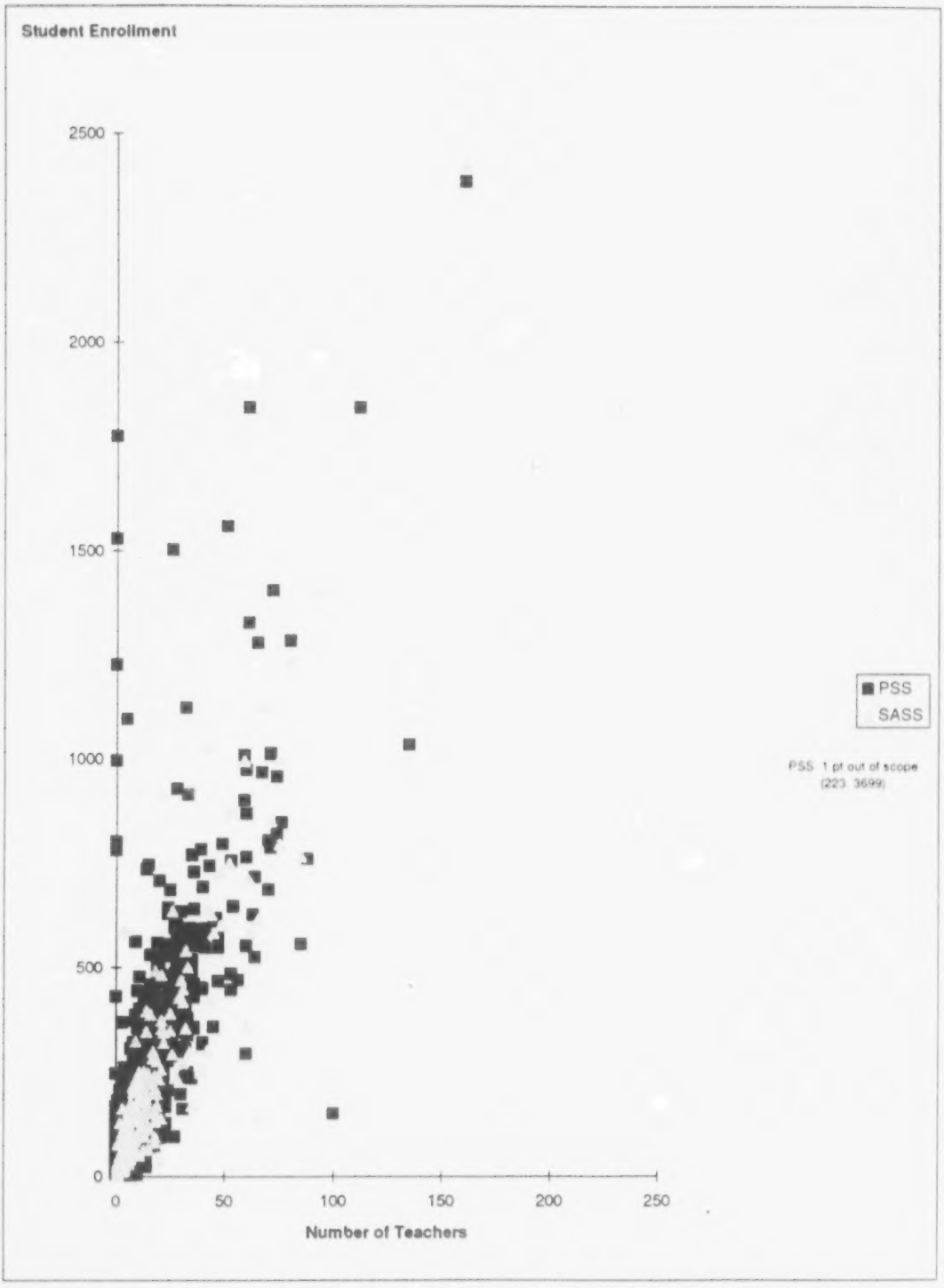
To set the stage for the calculations that follow, look at figure 6.1, which provides a scatterplot of student enrollment by number of teachers. The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. As can be seen, the SASS data points lie partly outside the parameters of the PSS data points, with almost no very large schools. The SASS data points do not even seem to lie along the same axis as those for PSS. In fact, the student/teacher ratios are quite different for PSS (17.2) and SASS (13.7).

These surveys are not for the same year but, if they were, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

3.6.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

Figure 6.1 -- **Other Unaffiliated**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

needed to be solved for the 238 sample cases in the Other Unaffiliated Typology. It can be derived from table 6.1 above that $\underline{d}$ is

$$\begin{matrix} 350 \\ 2{,}145 \\ 116{,}469 \end{matrix}$$

The matrix M was obtained by tabulating the 1990-91 SASS file for other unaffiliated schools. The values are

$$\begin{matrix} 238 & 3{,}539 & 47{,}866 \\ 3{,}539 & 148{,}887 & 1{,}929{,}096 \\ 47{,}866 & 1{,}929{,}096 & 28{,}407{,}364 \end{matrix}$$

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (1.616, -0.348, 0.025)$ and the modified GLS weights are of the form

$$u_i = w_i + 1.616 - 0.348t_i + 0.025s_i$$

Notice that all the original weights are increased on an overall basis (by about 1.6). The coefficient on the teacher total is quite large; because that coefficient is negative, the possibility of negative GLS weights exists, too. On the other hand, to compensate for the considerable shortfall in the total SASS student counts, a moderately-sized positive factor has been placed on the enrollment variable in the SASS sampled schools. Finally, while the values for $\underline{\lambda}$ are only shown to three decimal places, the calculations have been carried out in double precision.

3.6.2 Operational Characteristics.-- To evaluate the GLS adjustment described above, we will look at several diagnostics. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that for the original weights, w_i? The ratio of these two quantities turns out to be only a little larger than one (about 1.06)--an encouraging outcome. It suggests minimal or no harm may have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process.

The range of the weights is another measure worth calculating. This range shows the spread of the weights and any attenuation that may have occurred. Given the variance results above, it is not surprising to find that the range of the GLS weights is longer than for the original weights; however, this weight attenuation is by more than the small overall variance increase would suggest.

Original	1.1 to 71.2
GLS	-16.4 to 72.9

There were 13 SASS sample schools with negative weights and another four more sampled schools with positive weights of less than one. Why? The large shortage in the SASS student counts in SASS led to the need for a major adjustment. When the SASS teacher count, relative to enrollment, was larger than that in PSS, negative weights could and did occur. Overall, the variance of the GLS weights increased and the GLS weight range grew, relative to the weights originally on the file.

Figures 6.2 and 6.3 illustrate other operating characteristics of the original and GLS weights. Figure 6.2 shows both weight increases and decreases for schools with more teachers while weights for schools with smaller numbers of teachers remain much the same. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) The increases, of course, are for schools with very large enrollments and the decreases occur for schools with low student/teacher ratios. Incidentally, there is a corresponding decline in the simple correlation between the teacher total and the school weight (from about -0.37 to -0.40).

Figure 6.3 shows more clearly than seen earlier--this time by enrollment size--how the GLS weight always increases for schools with more students and declines or remains about the same for schools with smaller numbers of students. Accompanying this change, there is a corresponding decline in the absolute value of the simple correlation between enrollment and the school weight (from about -0.35 to -0.29).

We will comment on one more panel in figures 6.2 and 6.3, the scatterplot of GLS weights versus original weights. Not surprisingly, a strong relationship exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.6.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Other Unaffiliated Typology are available in table 6.2 and figure 6.4. Table 6.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 6.4 is another version of the data in table 6.2.

On a cell-by-cell basis, the relationship between the two versions of S SASS is fairly stable and predictable ($R^2 = .85$). Each is also closely related to the PSS.

Originally weighted SASS	vs PSS ($R^2 = .86$)
GLS-reweighted SASS	vs PSS ($R^2 = .69$)

The regression lines in figure 6.4, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

$$PSS = (0.82)SASS$$

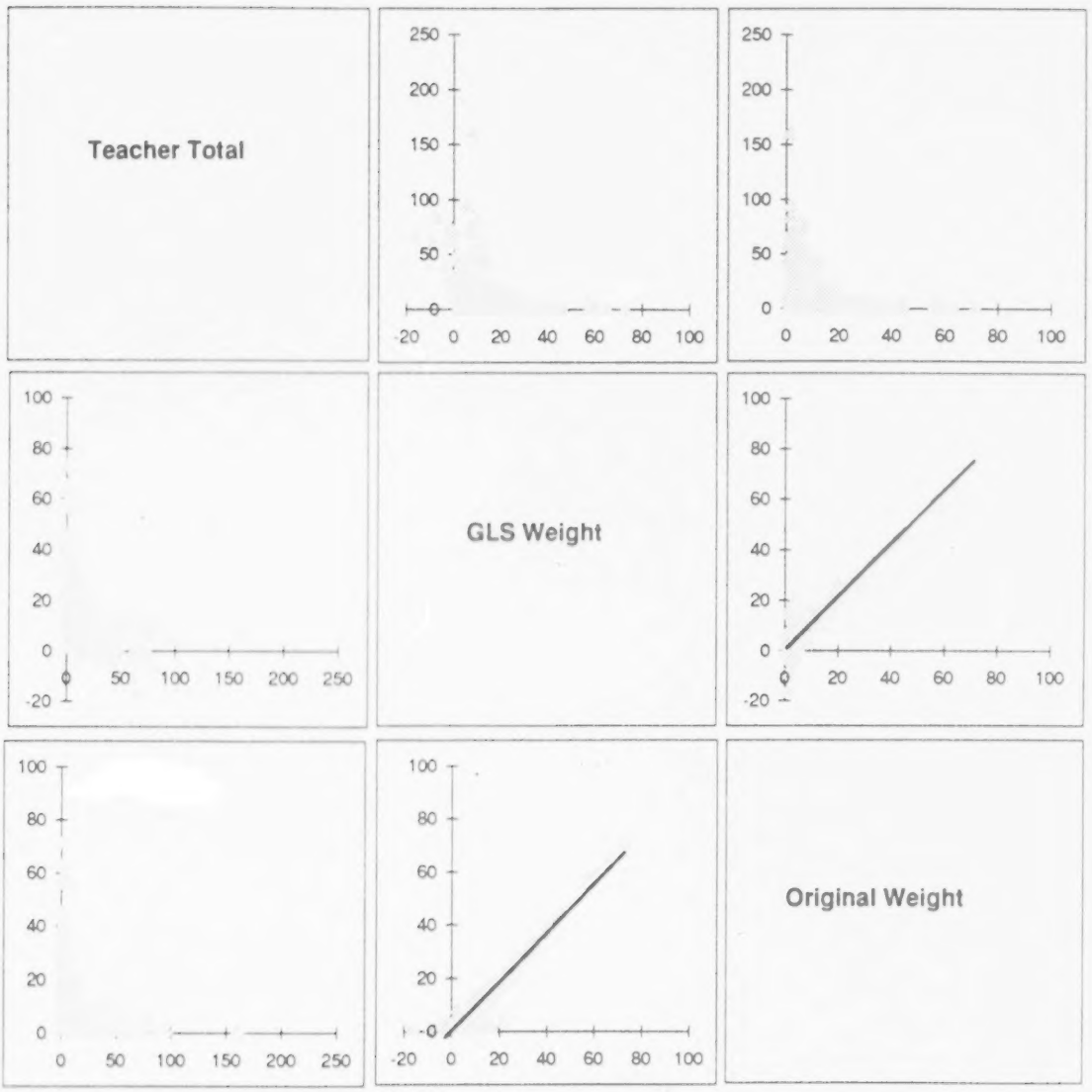
for the GLS-reweighted SASS data and

$$PSS = (1.29)SASS$$

for the original SASS data.

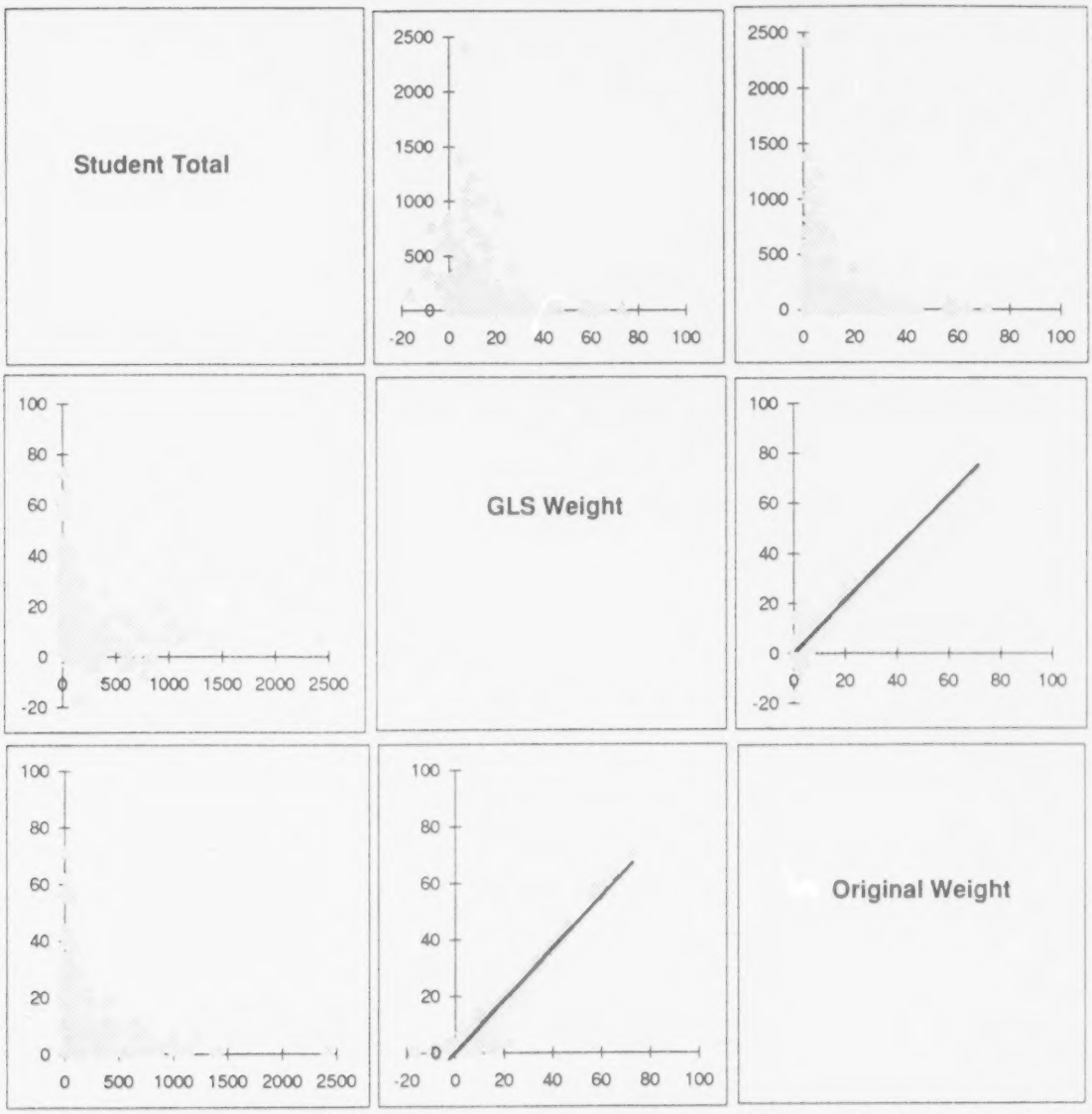
The difference in coefficients (0.82 versus 1.29) shows that the GLS-reweighted SASS data have achieved on average an overall greater closeness to the PSS than did SASS as originally weighted. Nonetheless, the results are quite disappointing, given that they were achieved at a considerable increase in variability. The R^2 values are a lot lower, for example, for the GLS data (at 0.69) than for the originally weighted estimates (at 0.86).

Figure 6.2 -- **Other Unaffiliated**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 6.3 -- **Other Unaffiliated**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



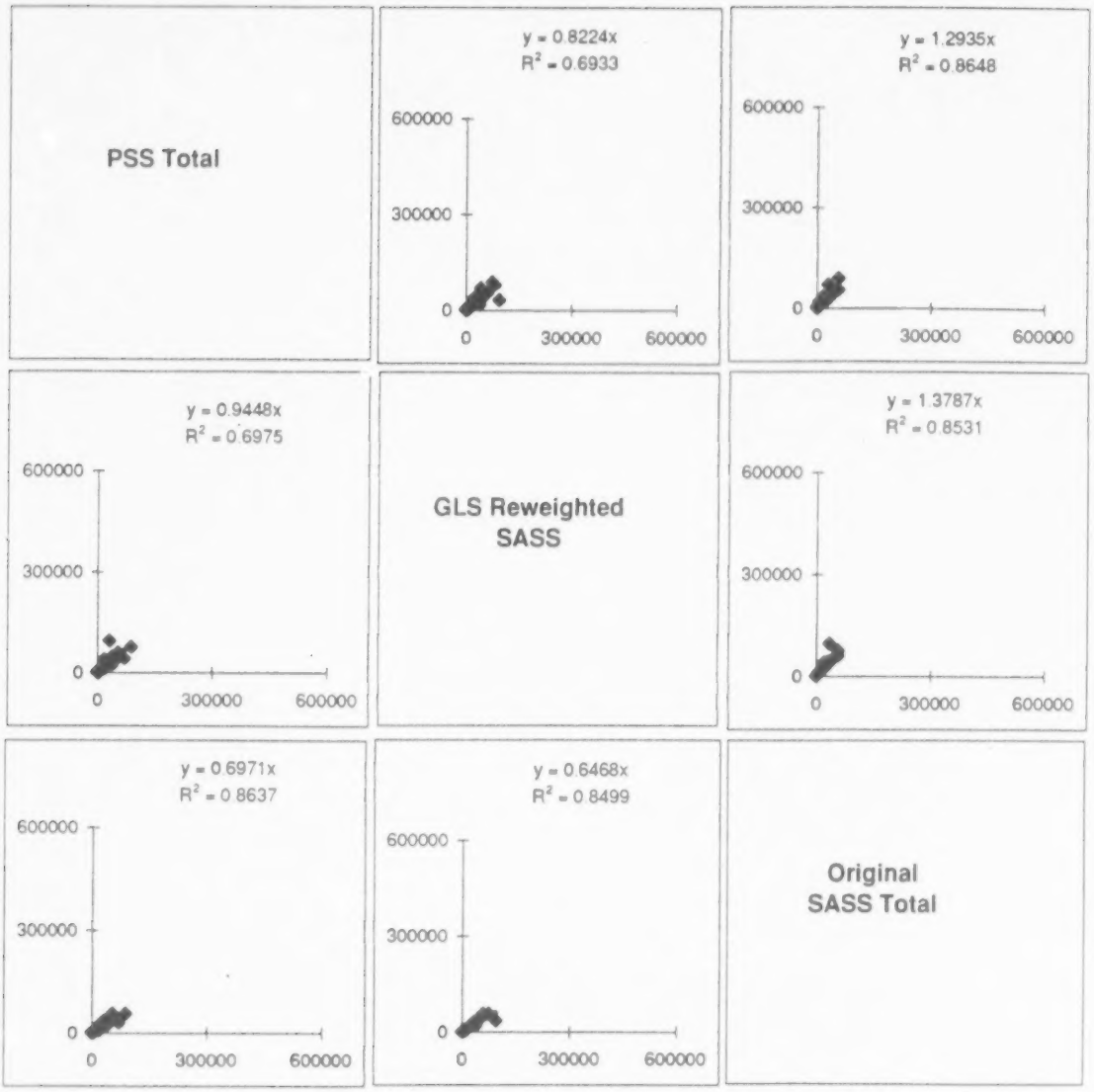
SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Table 6.2 -- **Other Unaffiliated**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type			Total
		Central City	Urban Fringe/ Large Town	Rural/ Small Town	
Part I - PSS Total					
1-149	School	707	684	1,224	2,615
	Teacher	3,122	2,551	3,696	9,369
	Student	45,385	39,305	54,206	138,896
150 - 499	School	349	279	166	794
	Teacher	4,525	3,854	2,208	10,587
	Student	88,014	70,250	38,878	197,142
500 - 749	School	29	31	6	66
	Teacher	1,095	992	210	2,297
	Student	17,205	18,721	3,208	39,134
750+	School	24	18	1	43
	Teacher	1,617	998	-	2,615
	Student	31,685	18,028	1,773	51,486
Total	School	1,109	1,012	1,397	3,518
	Teacher	10,359	8,395	6,114	24,868
	Student	182,289	146,304	98,065	426,658
Part II - Original SASS Total					
1 - 149	School	611	410	1,564	2,585
	Teacher	2,867	1,544	4,924	9,335
	Student	31,611	21,589	57,231	110,431
150 - 499	School	212	112	170	494
	Teacher	3,629	2,143	2,730	8,502
	Student	56,960	30,085	38,590	125,635
500 - 749	School	19	31	1	51
	Teacher	838	1,325	53	2,216
	Student	11,602	20,892	664	33,158
750+	School	33	6	--	39
	Teacher	2,322	349	--	2,671
	Student	35,086	5,879	--	40,965
Total	School	875	559	1,735	3,169
	Teacher	9,656	5,361	7,707	22,724
	Student	135,259	78,445	96,485	310,189
Part III - GLS Reweighted SASS Total					
1 - 149	School	660	453	1,636	2,749
	Teacher	1,835	1,619	5,053	8,507
	Student	33,533	24,105	59,865	117,503
150 - 499	School	273	141	194	608
	Teacher	4,335	1,717	2,816	8,868
	Student	74,998	37,386	45,773	158,157
500 - 749	School	18	59	1	78
	Teacher	673	1,676	50	2,399
	Student	11,563	38,083	628	50,274
750+	School	73	12	--	85
	Teacher	4,392	701	--	5,093
	Student	88,900	11,820	--	100,720
Total	School	1,024	665	1,831	3,520
	Teacher	11,235	5,713	7,919	24,867
	Student	208,994	111,394	106,266	426,654

SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 6.4 -- **Other Unaffiliated**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

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3.7 NONSECTARIAN REGULAR TYPOLOGY

The Nonsectarian Regular Typology consists of a moderate number of private schools. In the 1991-92 Private School Survey, this typology was estimated to have 2,376 schools, or 9.1 percent of the private school total for that year.

Table 7.1 -- 1991-92 PSS and Original 1990-91 Nonsectarian Regular SASS Totals Compared

	PSS	SASS
Schools	2,376	1,950
Teachers	43,380	38,828
Students	541,883	478,034

(Note: The numbers here may be different than the numbers in table 7.2 because of rounding.)

In table 7.1, a complete comparison is made between SASS and PSS estimates for schools, teachers, and students. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that all of the SASS totals are much lower than those from PSS: the school totals are about 18 percent too small; the weighted SASS teacher counts over 11 percent too low; and the SASS student totals are nearly 12 percent under PSS.

To set the stage for the calculations that follow, look at figure 7.1, which provides a scatterplot of student enrollment by number of teachers. The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. As can be seen, the SASS data points lie within the parameters of the PSS data points, and along the same axis. In fact, the student/teacher ratios are fairly close at 12.5 for PSS and 12.3 for SASS.

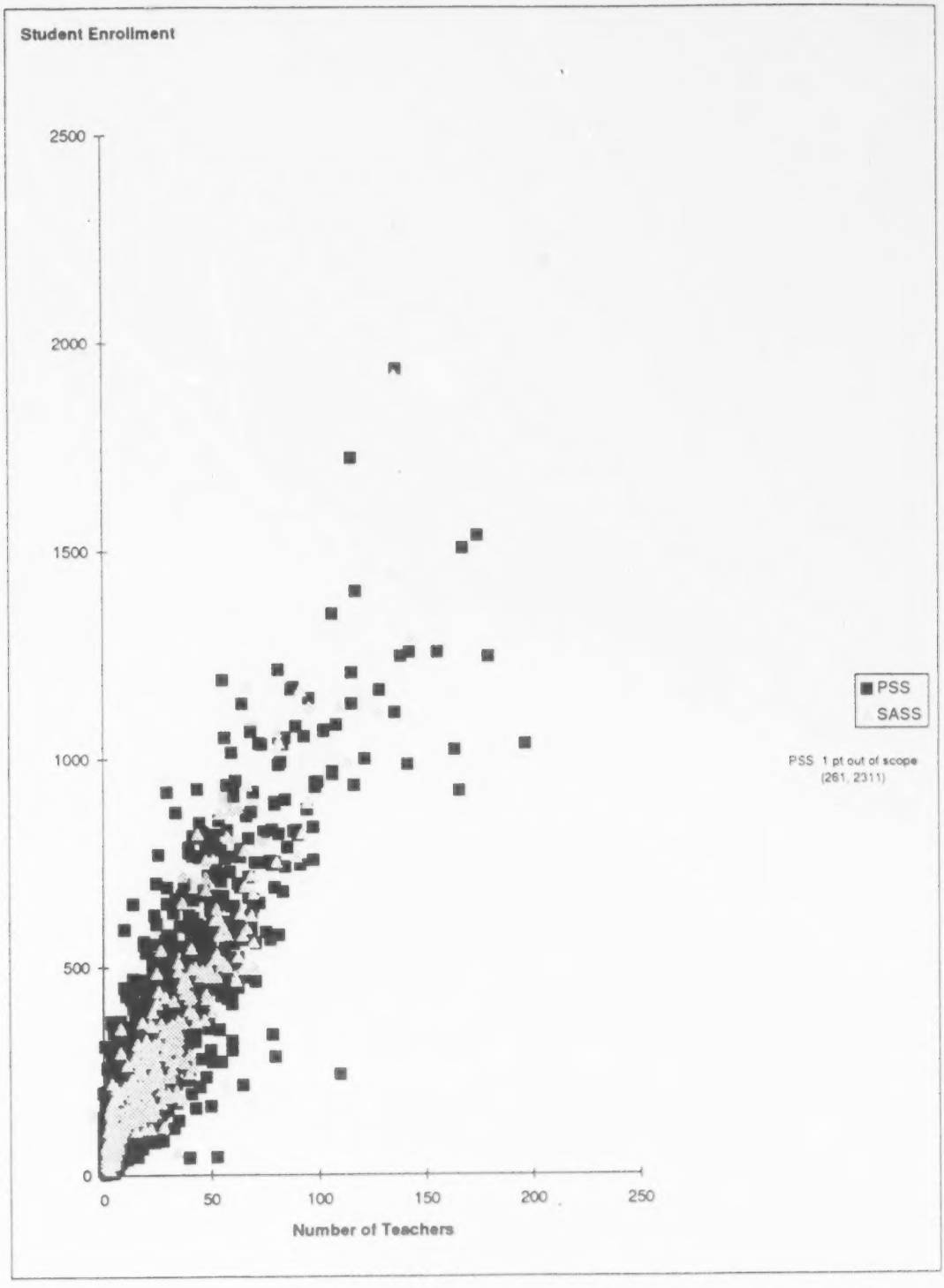
If these surveys were both for the same year, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

3.7.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

needed to be solved for the 280 sample cases in the nonsectarian regular

Figure 7.1 -- **Nonsectarian Regular**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

typology. It can be derived from table 7.1 above that $\underline{d}$ is

426

4,552

63,849

The matrix M was obtained by tabulating the 1990-91 SASS file for nonsectarian regular schools. The values are

280	8,649	97,595
8,649	517,099	5,469,206
97,595	5,469,206	62,999,127

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (2.586, -0.034, -0.000)$ and the modified GLS weights are of the form

$$u_i = w_i + 2.586 - 0.034t_i - 0.000s_i$$

Notice that the original weights are initially increased by almost 2.6. A modest downward adjustment is then made depending on the number of teachers that the SASS sample case has. Finally, a very slight downward correction is made based on the number of students in the SASS school. (The student adjustment is so small that it rounds to zero if the coefficient is shown, as above, only to three decimal places.) With this setup, there are naturally concerns about negative weights, a few of which do occur, as will be discussed below.

3.7.2 Operational Characteristics.-- To evaluate the GLS reweighting we will look at several diagnostics. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that for the original weights, w_i? The ratio of these two quantities turns out to be greater than one (about 1.17), suggesting that some (slight?) harm may have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process.

The range of the weights is another measure worth calculating. This range shows the spread of the weights and any attenuation that may have occurred. Given the variance results above, it is not surprising to find that the range of the GLS weights is a little longer than for the original weights.

Original	1.1 to 44.3
GLS	-2.3 to 46.8

The range includes some negative weights. In fact, four of these are negative and two more are positive but less than one. Why? Both the teacher and student

counts in SASS were below those in PSS (and by roughly the same proportion), while the school totals were even further off. What the modified GLS estimation did was to increase all the weights to begin with to "hit" the PSS school total. This alone would lead to an overestimation of teachers and students, so small downward adjustments were made that affected the largest schools the most--the very schools with the smallest weights to begin with. Overall, this increased the variance of the GLS weights and broadened their range, relative to those weights originally on the file.

Figures 7.2 and 7.3 illustrate other operating characteristics of the original and GLS weights. Figure 7.2 shows weight decreases for schools with more teachers and the corresponding lifting of the weights for schools with smaller numbers of teachers. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) Incidentally, there is a corresponding decline in the simple correlation between the teacher total and the school weight (from about -0.42 to -0.54).

Figure 7.3 also shows the same pattern observed earlier--this time by enrollment size--where the GLS weight increases for schools with only a few students and declines for schools with larger numbers of students. Again, there is a corresponding decline in the simple correlation between enrollment and the school weight (from about -0.37 to -0.48).

We will comment on one more panel in figures 7.2 and 7.3, the scatterplot of GLS weights versus original weights. Not surprisingly, a strong relationship exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.7.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Nonsectarian Regular Typology are available in table 7.2 and figure 7.4. Table 7.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 7.4 is another version of the data in table 7.2.

On a cell-by-cell basis, the relationship between the two versions of SASS is fairly stable and predictable ($R^2 = .97$). Each is also closely related to the PSS.

Originally weighted SASS	vs PSS ($R^2 = .94$)
GLS-reweighted SASS	vs PSS ($R^2 = .89$)

The regression lines in figure 7.4, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

$$PSS = (0.84)SASS$$

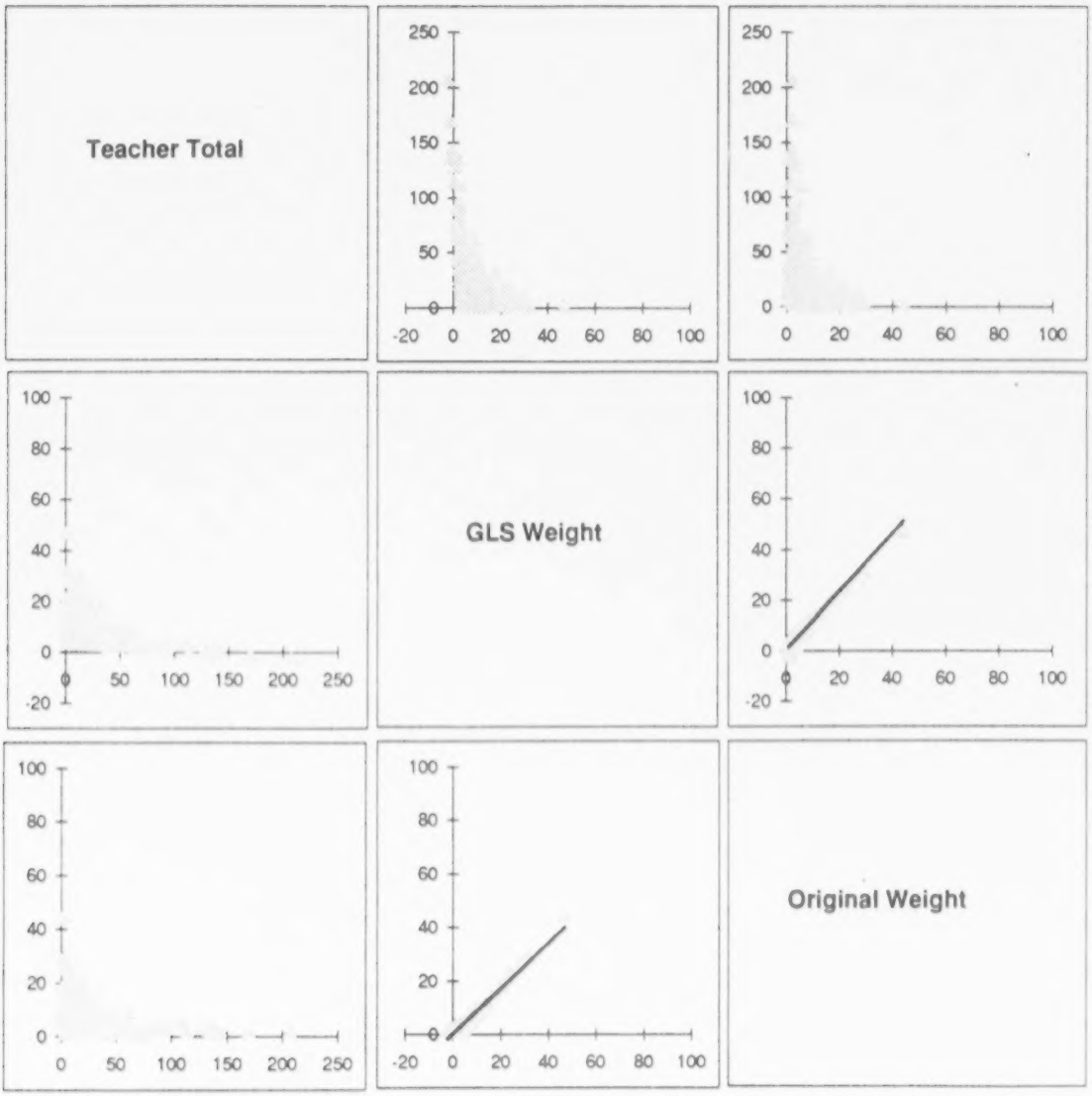
for the GLS-reweighted SASS data and

$$PSS = (1.04)SASS$$

for the original SASS data.

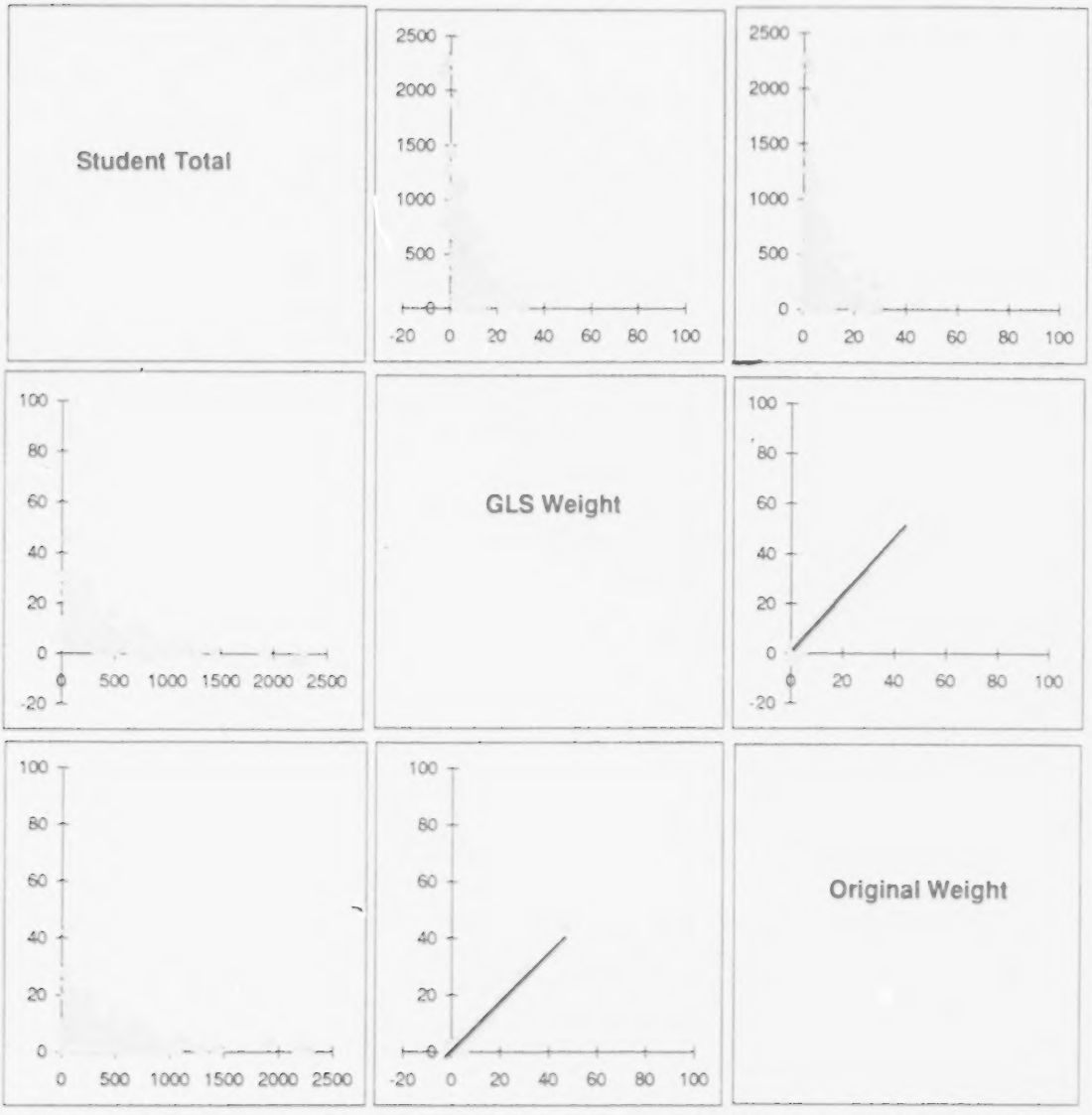
The difference in coefficients (0.84 versus 1.04) shows that the GLS-reweighted SASS data did not on average achieve an overall greater closeness to the PSS than did SASS as originally weighted. These results are even more disappointing given that the GLS data were also more variable. The R^2 values are lower, for example, for the GLS data (at 0.89) than for the originally weighted estimates (at 0.94).

Figure 7.2 -- **Nonsectarian Regular**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 7.3 -- **Nonsectarian Regular**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



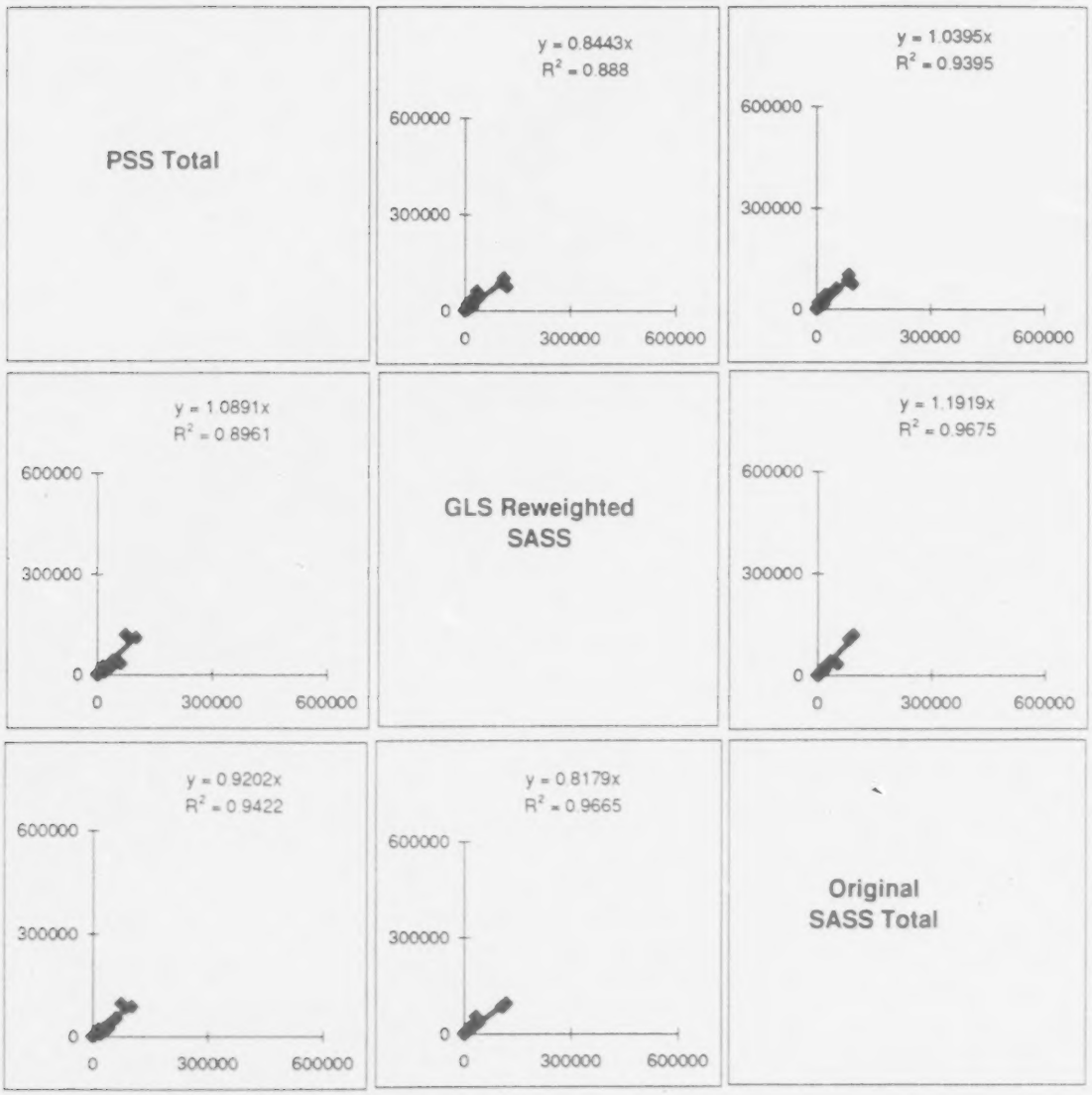
SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys,1990-91, Private School Surveys, 1991-92

Table 7.2 -- **Nonsectarian Regular**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type: Central City	Community Type: Urban Fringe/ Large Town	Community Type: Rural/ Small Town	Total
Part I - PSS Total					
1-149	School	610	349	215	1,174
	Teacher	2,924	1,988	1,332	6,244
	Student	42,185	26,197	14,895	83,277
150 - 499	School	363	314	265	942
	Teacher	7,858	6,477	6,106	20,441
	Student	102,268	85,038	75,217	262,523
500 - 749	School	71	48	33	152
	Teacher	3,667	2,367	1,349	7,383
	Student	42,389	27,873	19,673	89,935
750+	School	60	32	16	108
	Teacher	5,661	2,500	1,150	9,311
	Student	61,198	30,627	14,323	106,148
Total	School	1,104	743	529	2,376
	Teacher	20,110	13,332	9,937	43,379
	Student	248,040	169,735	124,108	541,883
Part II - Original SASS Total					
1 - 149	School	333	179	232	744
	Teacher	1,744	980	1,473	4,197
	Student	24,673	15,932	19,492	60,097
150 - 499	School	288	349	378	1,015
	Teacher	7,042	7,018	7,306	21,366
	Student	86,295	83,692	95,020	265,007
500 - 749	School	59	37	12	108
	Teacher	3,082	2,056	688	5,826
	Student	35,406	22,639	6,711	64,756
750+	School	48	18	18	84
	Teacher	4,858	1,629	953	7,440
	Student	53,268	19,147	15,758	88,173
Total	School	728	583	640	1,951
	Teacher	16,726	11,683	10,420	38,829
	Student	199,642	141,410	136,981	478,033
Part III - GLS Reweighted SASS Total					
1 - 149	School	402	223	280	905
	Teacher	2,129	1,275	1,815	5,219
	Student	29,659	19,862	23,613	73,134
150 - 499	School	369	440	471	1,280
	Teacher	9,059	8,951	9,242	27,252
	Student	111,315	106,321	118,602	336,238
500 - 749	School	69	43	15	127
	Teacher	3,620	2,320	812	6,752
	Student	41,726	25,788	8,556	76,070
750+	School	31	15	18	64
	Teacher	1,993	1,383	782	4,158
	Student	26,928	16,685	12,858	56,471
Total	School	871	721	784	2,376
	Teacher	16,801	13,929	12,651	43,381
	Student	209,628	168,656	163,629	541,913

SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 7.4 -- **Nonsectarian Regular**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

3.8 NONSECTARIAN SPECIAL EMPHASIS TYPOLOGY

The Nonsectarian Special Emphasis Typology represents a small group of private schools. In the 1991-92 Private School Survey, this typology was estimated to have 1,810 schools, or seven percent of the private school total for that year.

Table 8.1 -- 1991-92 PSS and Original 1990-91 Nonsectarian Special Emphasis SASS Totals Compared

	PSS	SASS
Schools	1,810	1,700
Teachers	13,724	18,718
Students	202,178	212,433

(Note: The numbers here may be different than the numbers in table 8.2 because of rounding.)

In table 8.1, SASS and PSS estimates are compared for schools, teachers, and students. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that the SASS school and student totals are between five percent and six percent of their PSS counterparts. On the other hand, the SASS teacher total is more than 36 percent higher than PSS. (This teacher comparison was so striking that the SASS file was examined indepth to try to ascertain why such a big and inconsistent difference existed. For more on the outlier found and what might be done in practice, see Holt et al. 1994.)

To set the stage for the calculations that follow, look at figure 8.1, which provides a scatterplot of student enrollment by number of teachers. The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. As can be seen, the SASS data points lie within the parameters of the PSS data points, but not completely along the same axis. In fact, the student/teacher ratios are 14.7 for PSS and 11.3 for SASS.

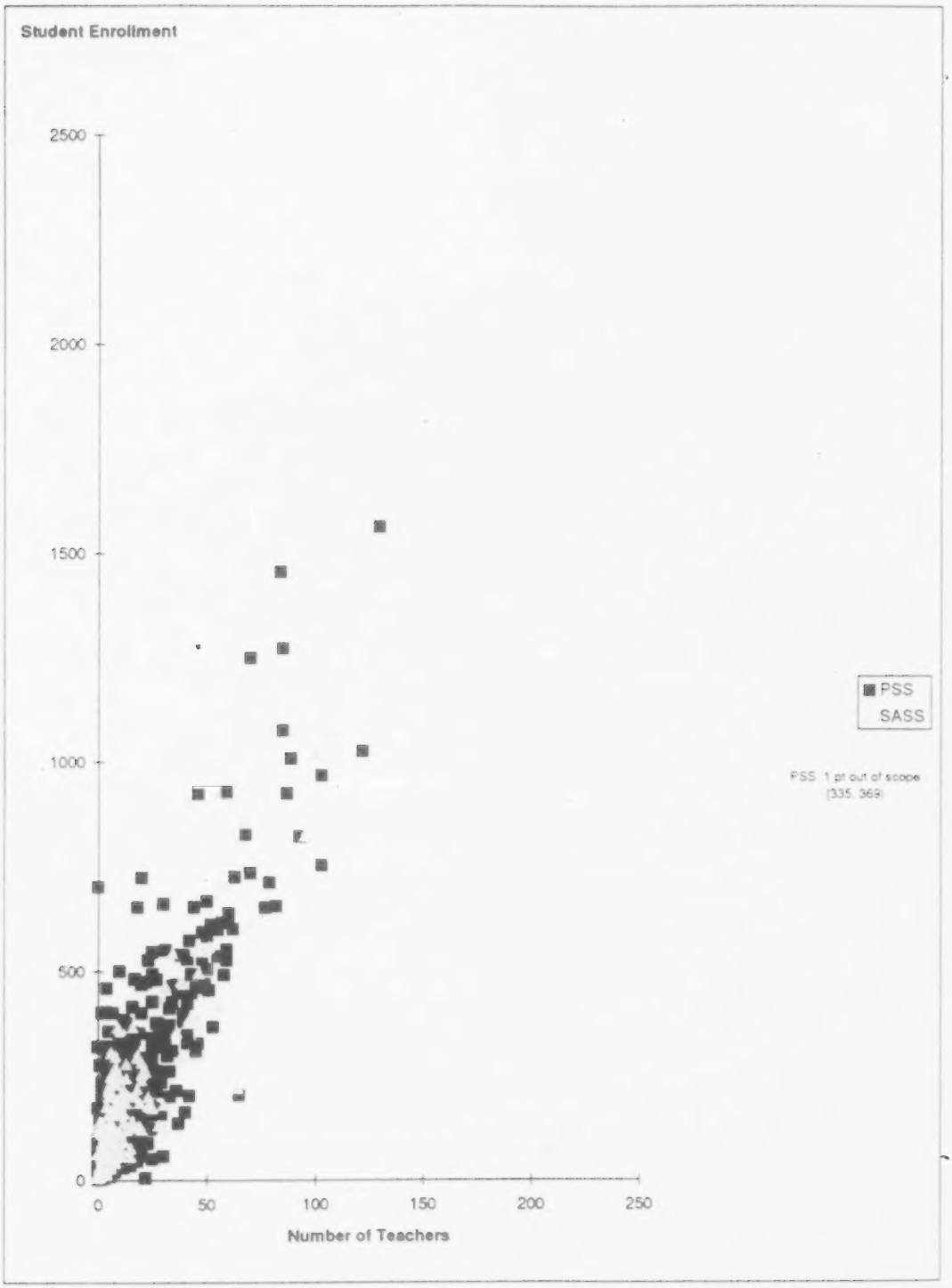
These surveys are not for the same year but, if they were, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

3.8.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

needed to be solved for the 205 sample cases in the nonsectarian special emphasis typology.

Figure 8.1 -- **Nonsectarian Special Emphasis**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

It can be derived from table 8.1 above that $\underline{d}$ is

110

-4,994

-10,255

The matrix M was obtained by tabulating the 1990-91 SASS file for the nonsectarian special emphasis schools. The values are

205	3,102	35,612
3,102	187,292	1,336,800
35,612	1,336,800	14,818,284

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (1.073, -0.059, 0.002)$ and the modified GLS weights are of the form

$$u_i = w_i + 1.073 - 0.059t_i + 0.002s_i$$

Notice that the original weights are initially increased by about 1.1. A moderately large downward adjustment is then made depending on the number of teachers that the SASS sample case has. Finally, a slight upward correction is made based on the number of students in the SASS school. This setup could cause negative weights, and they do occur, as will be discussed below.

3.8.2 Operational Characteristics.-- To evaluate the GLS weighting, we will examine several diagnostics. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that for the original weights, w_i? The ratio of these two quantities turns out to be somewhat greater than one (about 1.04), suggesting that some (slight?) harm may have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process.

The range of the weights may be another measure worth calculating. This range shows the spread of the weights and any attenuation that may have occurred. Given the variance results above, it is not surprising to find that the range of the GLS weights is longer than for the original weights.

Original	1.0 to 70.5
GLS	-3.5 to 71.4

Why? Both the school and student total in SASS were within six percent of PSS, but the teacher count in SASS was much too large, necessitating a sizable downward adjustment. For some large schools with small initial weights, this led to a negative result (despite an upward correction for the SASS student total). Overall, the

variance and range of the GLS weights were increased, relative to the weights originally on the file.

Figures 8.2 and 8.3 illustrate other operating characteristics of the original and GLS weights. Figure 8.2 shows weight declines for schools with more teachers and the compensating increase in weights for schools with smaller numbers of teachers. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) Incidentally, there is a corresponding decline in the simple correlation between the teacher total and the school weight (from about -0.14 to -0.27).

Figure 8.3, the scatterplot matrix for students by alternative SASS weights, does not show as clear a pattern as that observed for teachers. Enrollment size was not as closely related to the GLS weight as it was for the teacher total. Even so, there is a decline in the simple correlation between enrollment and the school weight (from about -0.22 originally to -0.29 for GLS), obviously not nearly as great as the decline in the correlation observed for teachers, but still worth noting.

We will comment on one more panel in figures 8.2 and 8.3, the scatterplot of GLS weights versus original weights. Not surprisingly given the GLS weight equation, a strong relationship exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.8.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Nonsectarian Special Emphasis Typology are available in table 8.2 and figure 8.4. Table 8.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 8.4 is another version of the data in table 8.2.

On a cell-by-cell basis, the relationship between the two versions of SASS is fairly stable and predictable ($R^2 = .98$). Each is also closely related to the PSS.

Originally weighted SASS	vs PSS ($R^2 = .87$)
GLS-reweighted SASS	vs PSS ($R^2 = .88$)

The regression lines in figure 8.4, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

$$PSS = (0.89)SASS$$

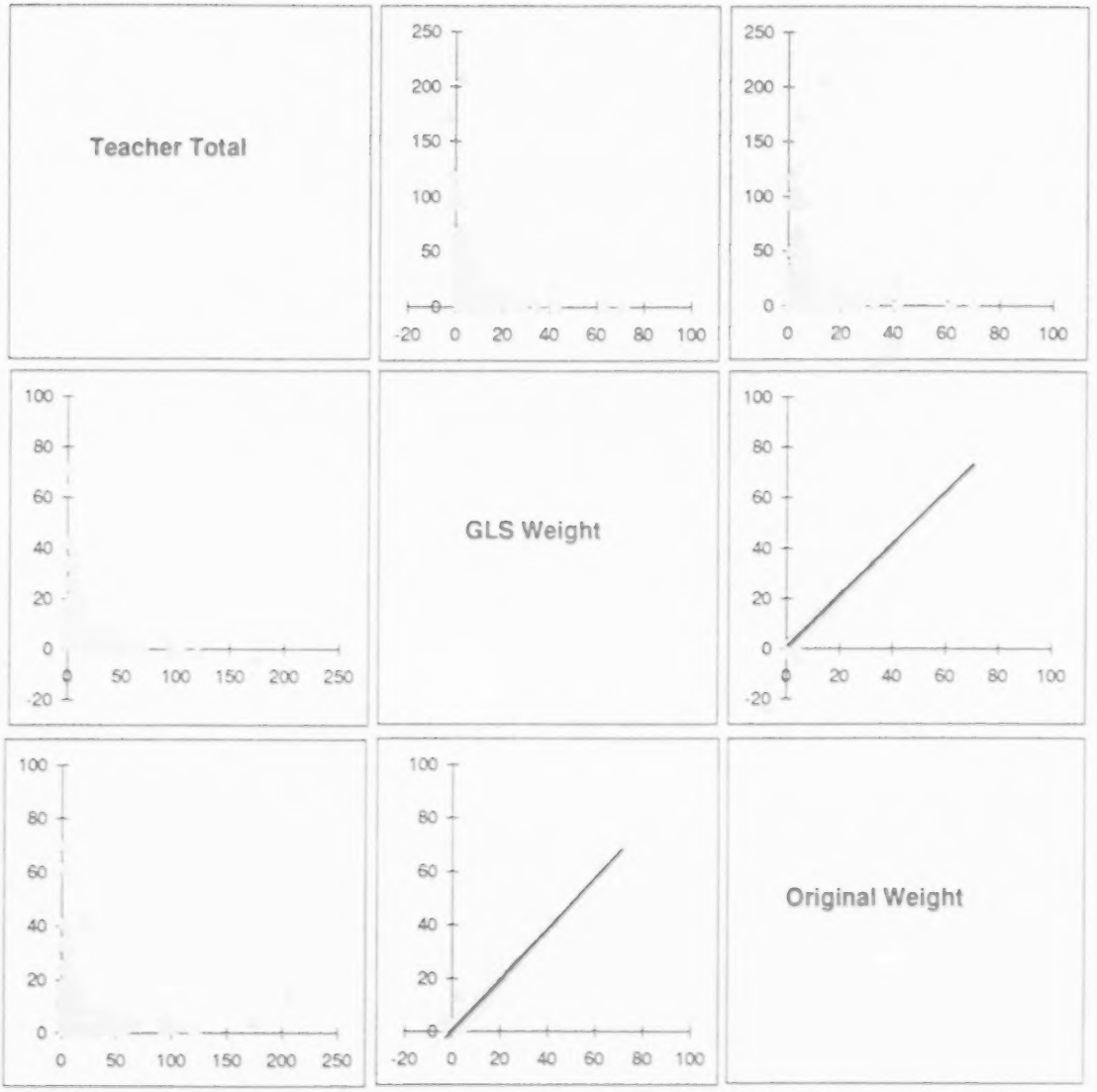
for the GLS-reweighted SASS data and

$$PSS = (0.94)SASS$$

for the original SASS data.

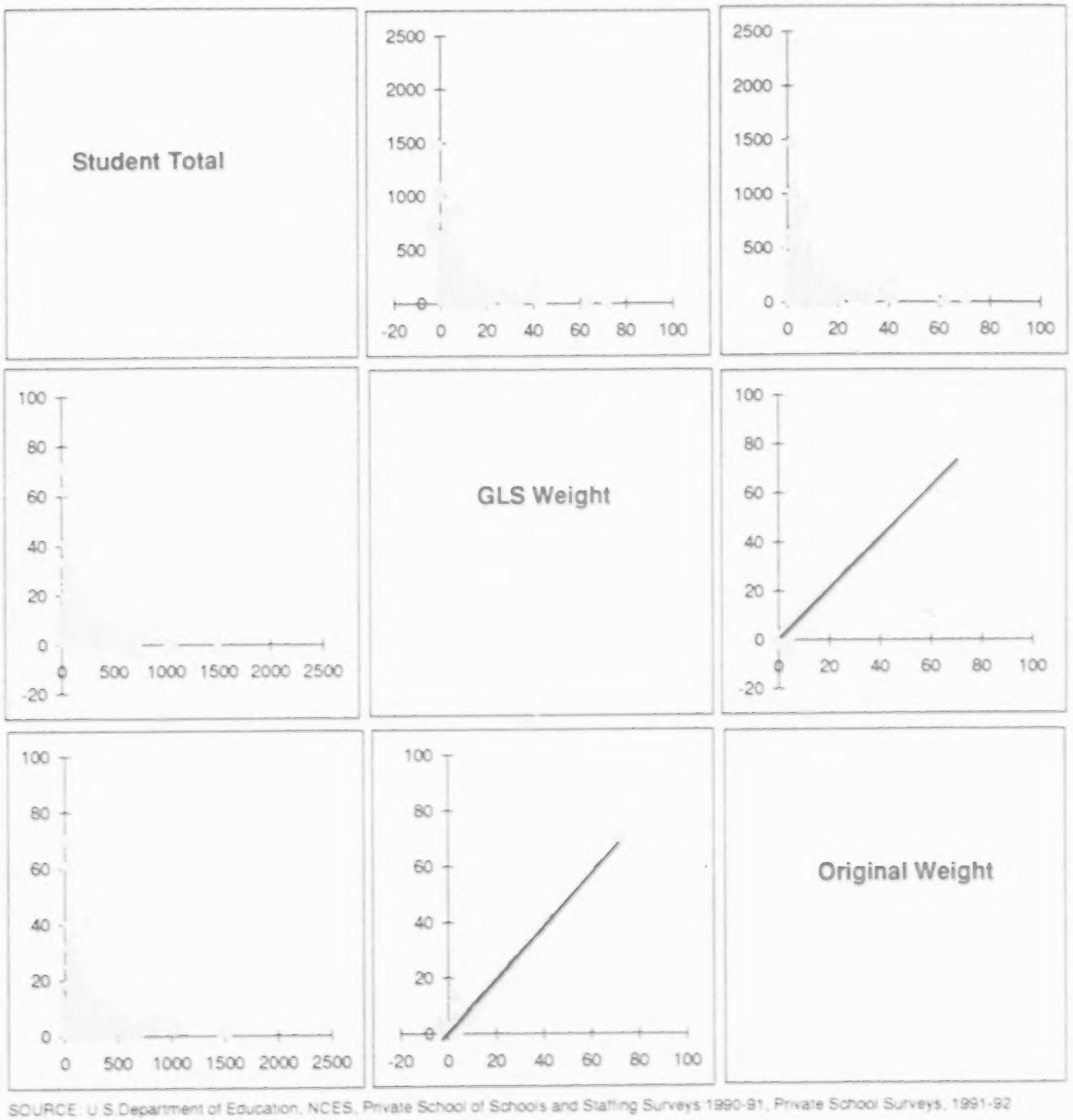
. The difference in coefficients (0.89 versus 0.94) shows that the GLS-reweighted SASS data did <u>not</u> achieve on average as good an overall closeness to the PSS as did the originally weighted SASS. These results are quite disappointing, despite the fact that the variability of the two estimates was about the same, as seen in the R^2 values already shown above.

Figure 8.2 -- **Nonsectarian Special Emphasis**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys 1990-91, Private School Surveys, 1991-92

Figure 8.3 -- **Nonsectarian Special Emphasis**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys 1990-91, Private School Surveys, 1991-92

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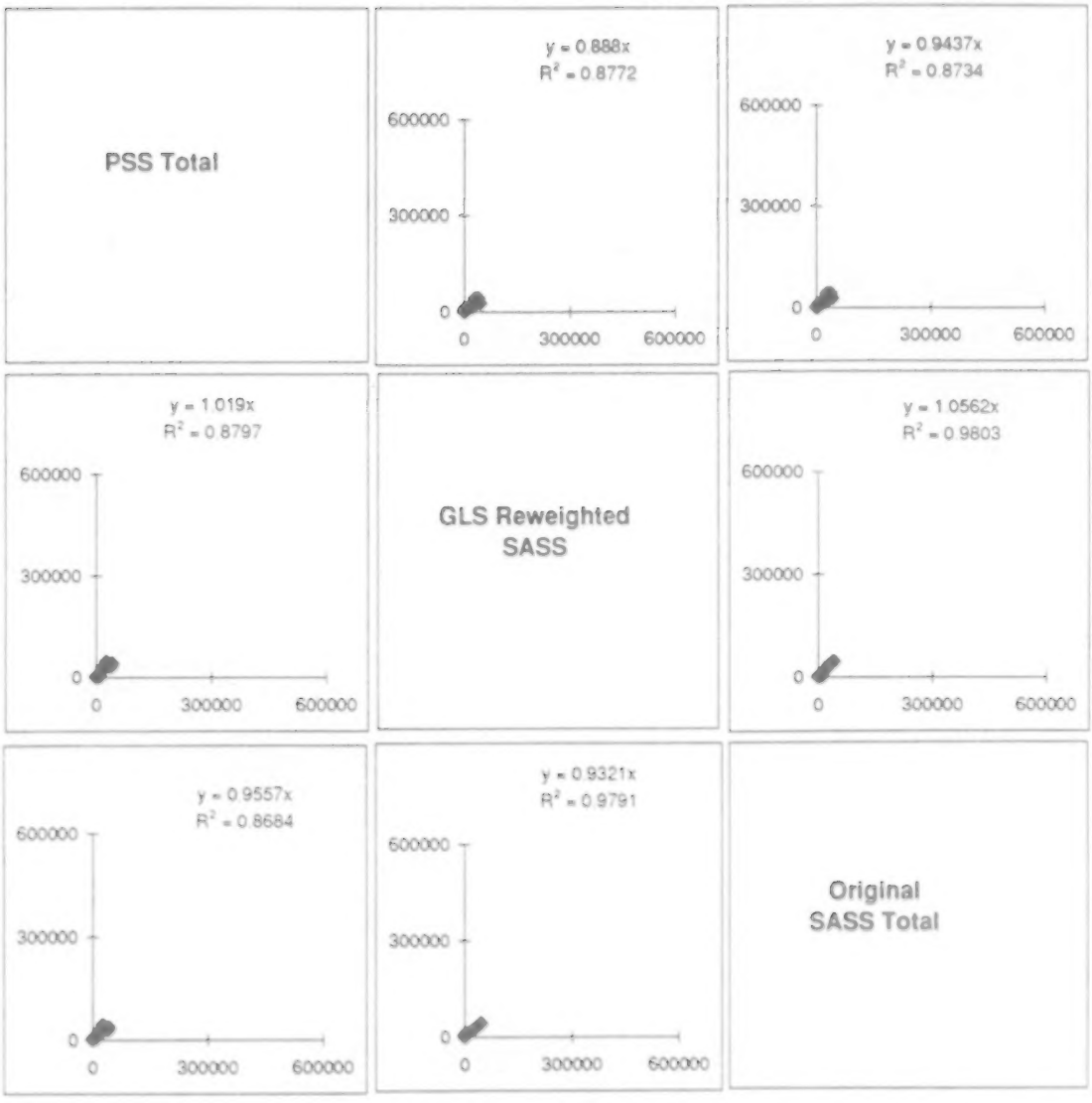
Table 8.2 -- **Nonsectarian Special Emphasis**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type: Central City	Community Type: Urban Fringe/ Large Town	Community Type: Rural/ Small Town	Total
Part I - PSS Total					
1-149	School	684	495	271	1,450
	Teacher	2,983	1,883	1,137	6,003
	Student	42,861	31,850	15,889	90,600
150 - 499	School	166	110	34	310
	Teacher	2,187	1,965	667	4,819
	Student	40,324	26,744	8,012	75,080
500 - 749	School	15	17	2	34
	Teacher	685	859	63	1,607
	Student	9,260	10,279	1,312	20,851
750+	School	7	6	1	14
	Teacher	652	582	60	1,294
	Student	8,678	6,019	950	15,647
Total	School	872	628	308	1,808
	Teacher	6,507	5,289	1,927	13,723
	Student	101,123	74,892	26,163	202,178
Part II - Original SASS Total					
1 - 149	School	580	353	363	1,296
	Teacher	2,522	1,917	4,531	8,970
	Student	37,136	28,705	24,025	89,866
150 - 499	School	116	181	56	353
	Teacher	1,689	2,623	1,596	5,908
	Student	27,908	43,041	11,596	82,545
500 - 749	School	17	11	2	30
	Teacher	922	946	161	2,029
	Student	10,136	6,565	1,141	17,842
750+	School	8	10	6	24
	Teacher	741	538	534	1,813
	Student	8,634	8,923	4,625	22,182
Total	School	721	555	427	1,703
	Teacher	5,874	6,024	6,822	18,720
	Student	83,814	87,234	-- 41,387	212,435
Part III - GLS Reweighted SASS Total					
1 - 149	School	636	386	381	1,403
	Teacher	2,779	2,052	2,351	7,182
	Student	41,138	31,378	25,094	97,610
150 - 499	School	133	196	53	382
	Teacher	1,834	2,668	1,376	5,878
	Student	31,708	46,076	10,536	88,320
500 - 749	School	13	3	(1)	15
	Teacher	657	(388)	(132)	137
	Student	7,404	968	(937)	7,435
750+	School	1	8	3	12
	Teacher	(22)	285	263	526
	Student	(63)	6,592	2,281	8,810
Total	School	783	593	436	1,812
	Teacher	5,248	4,617	3,858	13,723
	Student	80,187	85,014	36,974	202,175

SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys 1990-91, Private School Surveys, 1991-92

Figure 8.4 -- **Nonsectarian Special Emphasis**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys 1990-91, Private School Surveys, 1991-92

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3.9 NONSECTARIAN SPECIAL EDUCATION TYPOLOGY

The Nonsectarian Special Education typology is among the smaller private school types. In the 1991-92 Private School Survey, this typology was estimated to number 1,163 schools, or just 4.5 percent of the private school total for that year.

Table 9.1 -- 1991-92 PSS and Original 1990-91 Nonsectarian Special Education SASS Totals Compared

	PSS	SASS
Schools	1,163	833
Teachers	12,668	10,089
Students	80,264	65,017

(Note: The numbers here may be different than the numbers in table 9.2 because of rounding.)

In table 9.1, a complete comparison is made between SASS and PSS estimates for schools, teachers, and students. Bringing these three SASS totals in line with the corresponding PSS ones is the exercise to be engaged in here. Notice that all the SASS totals are considerably lower: schools by over 28 percent, teachers by over 20 percent, and students by about 19 percent.

To set the stage for the calculations that follow, look at figure 9.1, which provides a scatterplot of student enrollment by number of teachers. The PSS schools are shown as black squares. The SASS data, shown as gray triangles, overlay the PSS data. As can be seen, the SASS data points lie within the parameters of the PSS data points, and along the same axis. In fact, the student/teacher ratios are 6.3 for PSS and 6.4 for SASS.

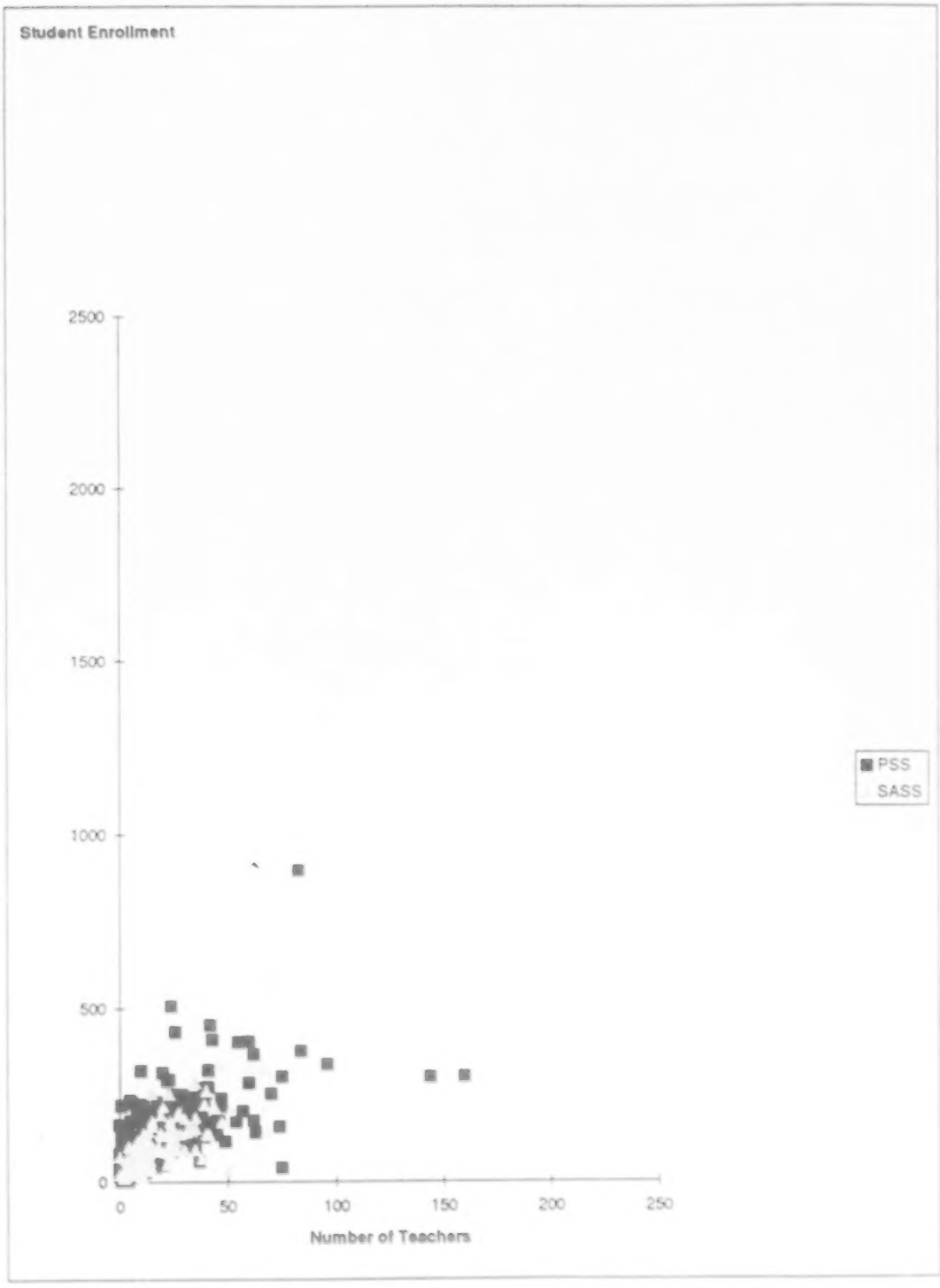
If these surveys were both for the same year, the expected values for the PSS and corresponding SASS quantities would be the same, so an estimator that makes them equal is an appropriate condition to impose. To simulate this possibility, a modified GLS estimator is constructed to calibrate the 1990-91 SASS to the 1991-92 PSS.

3.9.1 Procedure Employed.-- To carry out the modified GLS weighting, the equation described in section 2

$$\underline{\lambda} = M^{-1}\underline{d}$$

needed to be solved for the 128 sample cases in the Nonsectarian Special Education typology.

Figure 9.1 -- **Nonsectarian Special Education**
Teacher and Student Totals
PSS and SASS Combined



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys,1990-91; Private School Surveys, 1991-92

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It can be derived from table 9.1 above that $\underline{d}$ is

330

2,579

15,247

The matrix M was obtained by tabulating the 1990-91 SASS file for nonsectarian special emphasis schools. The values are

128	2,211	12,940
2,211	63,493	326,479
12,940	326,479	2,089,762

Solving for $\underline{\lambda}$ yields $\underline{\lambda}' = (5.169, -0.063, -0.015)$ and the modified GLS weights are of the form

$$u_i = w_i + 5.169 - 0.063t_i - 0.015s_i$$

Notice that the original weights are initially increased by almost 5.2. A modest downward adjustment is then made depending on the number of teachers that the SASS sample case has. Finally, another downward correction is made based on the number of students in the SASS school. With this setup, concerns exist about negative weights, and a few of them do occur, as will be discussed below.

3.9.2 Operational Characteristics.-- To examine the GLS adjustment, we will look at several diagnostics. One statistic that merits immediate attention is what happened to the spread in the weights themselves. Did the spread grow larger or smaller? Specifically, how much larger (smaller) is the variance of the new weights, u_i, relative to that for the original weights, w_i? The ratio of these two quantities turns out to be greater than one (about 1.22), suggesting some harm may have occurred in SASS statistics not closely linked to the three quantities being used in the adjustment process.

The range of the weights is another measure worth calculating. This range shows the spread of the weights and any attenuation that may have occurred. Given the variance results above, it is not surprising to find that the range of the GLS weights is a good bit longer than for the original weights.

Original	1.1 to 41.3
GLS	-6.6 to 45.4

In fact there were three SASS cases with negative weights and four more with positive weights of less than one.

Figures 9.2 and 9.3 illustrate other operating characteristics of the original and GLS weights. Figure 9.2 shows weight declines for schools with more teachers and the corresponding increases in weights for schools with smaller numbers of teachers. (Compare the scatterplots of teachers versus GLS weights and teachers versus original weights.) Incidentally, there is a corresponding decline in the simple correlation between the teacher total and the school weight (from about -0.32 to -0.50).

Figure 9.3 shows the same pattern observed earlier--this time by enrollment size--where the GLS weight declines for schools with more students and increases for schools with smaller numbers of students. Again, there is a corresponding decline in the simple correlation between enrollment and the school weight (from about -0.26 to -0.45).

We will comment on one more panel in figures 9.2 and 9.3, the scatterplot of GLS weights versus original weights. Notice the strong relationship that exists between the original and corresponding GLS weights. This linkage helps explain the results discussed next.

3.9.3 Independent Assessments.-- Some of the ingredients for an independent assessment of the GLS adjustment of the Nonsectarian Special Education typology are available in table 9.2 and figure 9.4. Table 9.2 is a cross-tabulation of PSS and SASS by community type and school size. Within each combination of these, totals for schools, teachers, and students can be compared for PSS with either the original or GLS-reweighted SASS. The scatterplot matrix in figure 9.4 is another version of the data in table 9.2.

On a cell-by-cell basis, the relationship between the two versions of SASS is fairly stable and predictable ($R^2 = .99$). Each is also closely related to the PSS.

Originally weighted SASS	vs PSS ($R^2 = .96$)
GLS-reweighted SASS	vs PSS ($R^2 = .93$)

The regression lines in figure 9.4, moreover, give a way of delving analytically into the underlying structure of these relationships. In particular, these can be written approximately in the form

$$PSS = (0.85)SASS$$

for the GLS-reweighted SASS data and

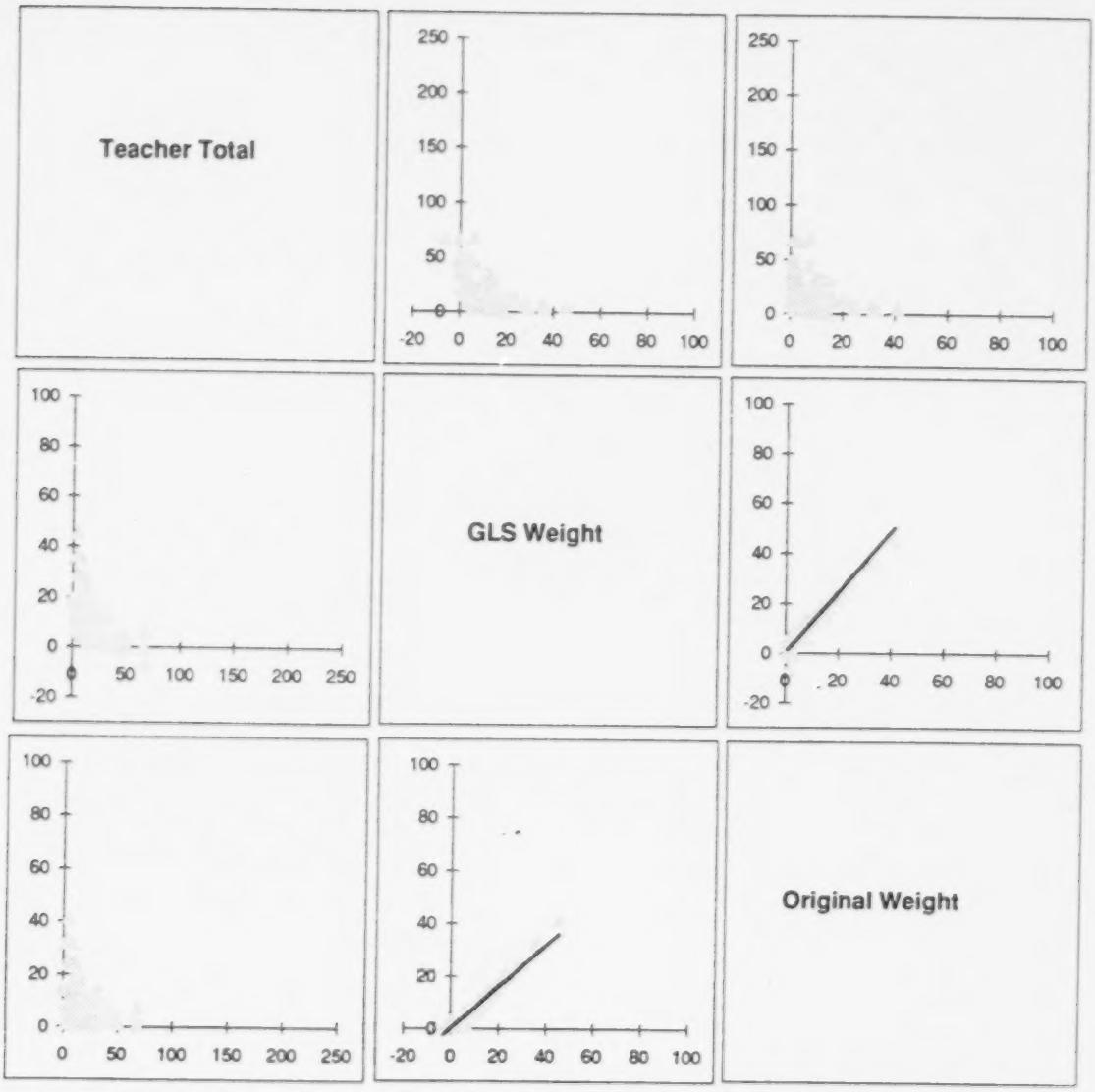
$$PSS = (1.19)SASS$$

for the original SASS data.

The difference in coefficients (0.85 versus 1.19) shows that the GLS-reweighted SASS data have achieved on average a somewhat greater closeness to the PSS than did SASS as

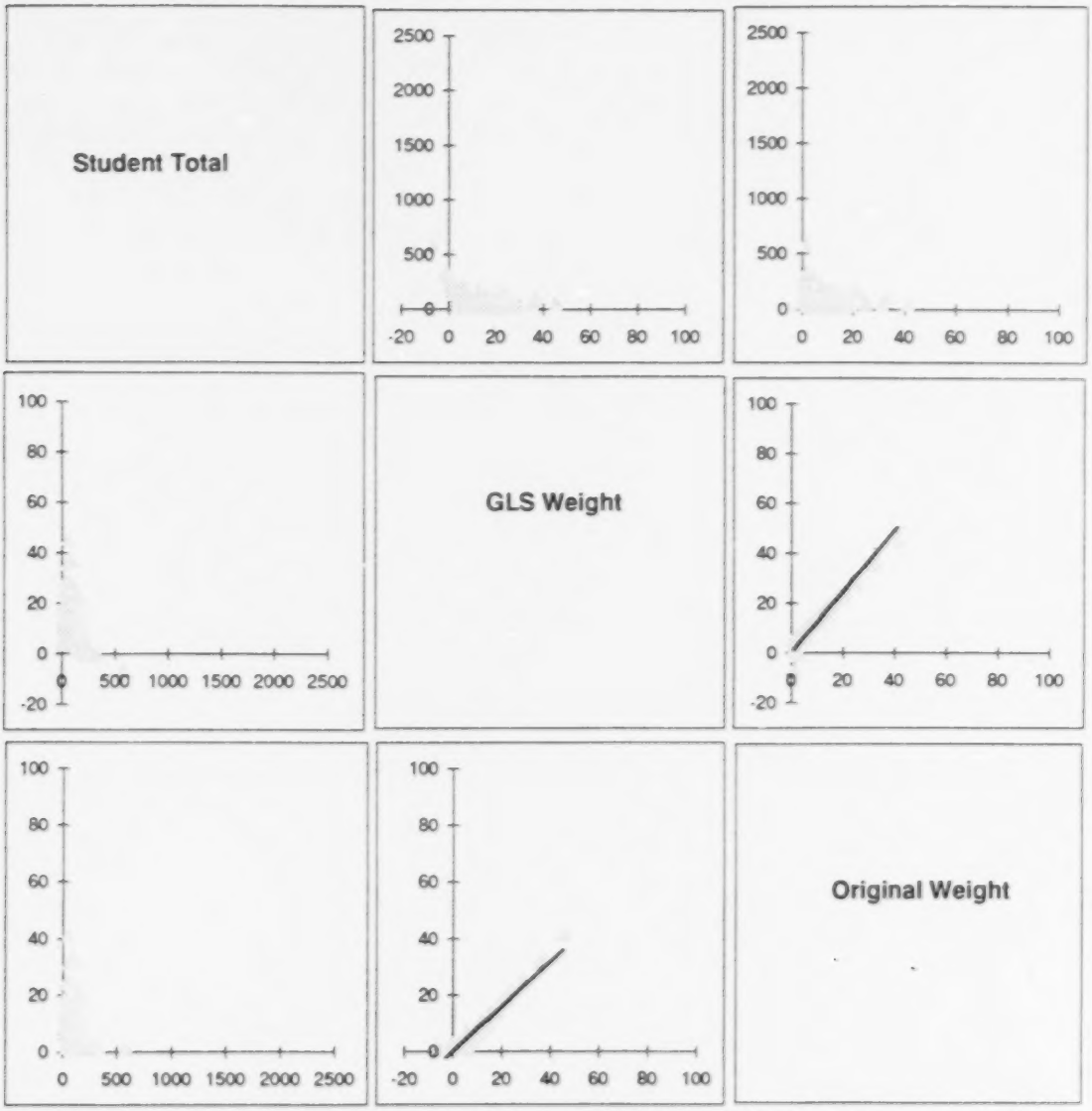
originally weighted. Moreover, since the R^2 values are virtually identical, it appears that this improvement in the mean was not at the expense of much roughening in the variance. Even so the improvement due to GLS is only marginally better.

Figure 9.2 -- **Nonsectarian Special Education**
Scatterplot Matrix of Teacher Totals by Original and GLS Weight



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 9.3 -- **Nonsectarian Special Education**
Scatterplot Matrix of Student Enrollment by Original and GLS Weight



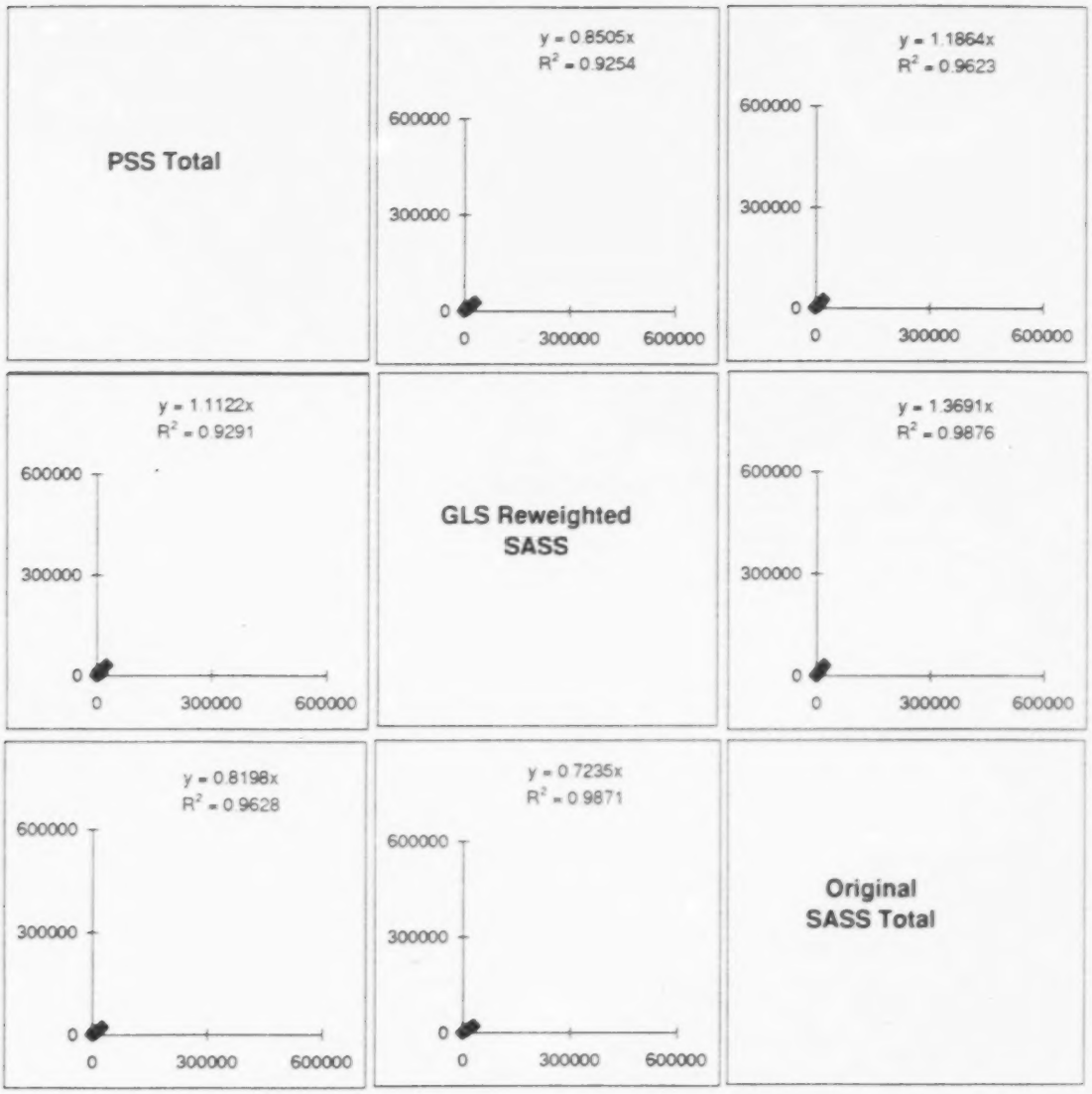
SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Table 9.2 -- **Nonsectarian Special Education**
School Size and Community Type, PSS and SASS Compared

School Size		Community Type: Central City	Community Type: Urban Fringe/ Large Town	Community Type: Rural/ Small Town	Total
Part I - PSS Total					
1-149	School	438	464	147	1,049
	Teacher	3,582	4,265	1,165	9,012
	Student	22,352	25,954	6,635	54,941
150 - 499	School	58	44	10	112
	Teacher	1,765	1,462	321	3,548
	Student	12,179	9,569	2,144	23,892
500 - 749	School	--	1	--	1
	Teacher	--	25	--	25
	Student	--	527	--	527
750+	School	1	--	--	1
	Teacher	84	--	--	84
	Student	904	--	--	904
Total	School	497	509	157	1,163
	Teacher	5,431	5,752	1,486	12,669
	Student	35,435	36,050	8,779	80,264
Part II - Original SASS Total					
1 - 149	School	289	306	159	754
	Teacher	3,192	3,529	1,099	7,820
	Student	19,081	21,338	9,344	49,763
150 - 499	School	36	40	1	77
	Teacher	877	1,255	59	2,191
	Student	6,898	7,449	239	14,586
500 - 749	School	--	1	--	1
	Teacher	--	79	--	79
	Student	--	667	--	667
750+	School	--	--	--	-
	Teacher	--	--	--	-
	Student	--	--	--	-
Total	School	325	347	160	832
	Teacher	4,069	4,863	1,158	10,090
	Student	25,979	29,454	9,583	65,016
Part III - GLS Reweighted SASS Total					
1 - 149	School	411	442	236	1,089
	Teacher	4,300	5,094	1,806	11,200
	Student	26,565	30,412	13,436	70,413
150 - 499	School	38	41	-	79
	Teacher	749	1,163	3	1,915
	Student	6,654	6,979	13	13,646
500 - 749	School	--	(7)	--	(7)
	Teacher	--	(446)	--	(446)
	Student	--	(3,793)	--	(3,793)
750+	School	--	--	--	-
	Teacher	--	--	--	-
	Student	--	--	--	-
Total	School	449	476	236	1,161
	Teacher	5,049	5,811	1,809	12,669
	Student	33,219	33,598	13,449	80,266

SOURCE: U.S Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

Figure 9.4 -- **Nonsectarian Special Education**
Scatterplot Matrix of School and Community Type Totals
PSS, Original and Reweighted SASS



SOURCE: U.S.Department of Education, NCES, Private School of Schools and Staffing Surveys:1990-91, Private School Surveys, 1991-92

4. SUMMARY AND RECOMMENDATIONS

At this stage it is hard to do more than conjecture about next steps in terms of the 1993-94 SASS. Even so, a few observations are of general interest.

4.1 SUMMARY

The results of the nine typologies tested here are decidedly mixed. (See table 4.1.) For some typologies--Catholic Parochial, Catholic Private, Conservative Christian, and Other Affiliated--the operational assessment shows the impact of the adjustment on SASS at least did no apparent harm; the independent assessment shows it may have even been of benefit. For three others--Other Unaffiliated, Nonsectarian Regular, and Nonsectarian Special Emphasis--the GLS adjustment may have caused severe problems. These results are beyond the basic consistency all typologies achieved with PSS.

Table 4.1.-- Typology-by-Typology GLS Comparisons

SASS Typology	Operational Assessment	Independent Assessment
Catholic Parochial	good	good
Catholic Diocesan	poor	fair
Catholic Private	good	good
Conservative Christian	good	good
Other Affiliated	fair	good
Other Unaffiliated	poor	bad
Nonsectarian Regular	poor	bad
Nonsectarian Special Emphasis	poor	bad
Nonsectarian Special Education	poor	fair

A closer look at the cases where no apparent harm occurred reveals that these were situations where almost no adjustment was needed to begin with. This makes it reasonable to assume that fair to good results should be expected for the application of GLS to the 1993-94 SASS. After all, unlike in the test done for this report, both PSS and SASS were collected for the same school year.

Since we tried only a few experiments to handle negative weights, we cannot report in any detail. However, a number of methods that dampen the effects of negative weights or even eliminate them seem practical (e.g., Huang 1978). It is also plausible to suppose that these methods may not even be needed, or, if needed, would be required infrequently in the proposed application to the 1993-94 PSS and 1993-94 SASS.

The experience gained in compiling operational statistics on the workings of the GLS adjustments was instructive. Only some of these variables may need to be tracked, though, since they so frequently gave the same bottom line.

Independently assessing the GLS reweighting proved particularly instructive and allowed both bias and variance effects to be examined. Using some of this additional information in the adjustment might have improved results but retaining at least some outside data for evaluation has a value, too.

The use of a modified GLS reweighting, even when it is beneficial, does not make much of a positive difference beyond achieving consistency with PSS. Other methods, done separately or in combination with GLS, appear needed to take full advantage of the opportunity offered by having PSS and SASS fielded for the same year.

4.2 RECOMMENDATIONS FOR THE FUTURE

Some recommendations are implied in the summary discussion given above. Nonetheless, these will be repeated again and augmented by observations that are more conjectural or of a basic research nature. **An overriding concern is that it is hard to predict when the GLS estimator will perform well and when it will not. Therefore, except for special circumstances, an unmodified GLS approach should not be adopted.** Additional specific recommendations include those given below.

4.2.1 Do GLS for 1993-94.-- The 1993-94 SASS will benefit by employing a GLS adjustment, especially given the expected closeness that should exist in any case.

If the adjustments made are as small as expected, there will be little if any need to recalculate the sampling errors prior to their use.

For the longer run, methods for variance estimation need exploration. While the general GLS approach is well covered in the literature, an efficient method has to be programmed and tested in the SASS environment. Of course, concerns also exist about the impact on variance and variance estimation of the various ad hoc adaptations needed to keep the weights reasonable.

4.2.2 Refine the GLS Application.-- Without a lot more work, it appears highly unlikely that GLS procedures for SASS will become routine any time soon. For one thing, much

greater control of how the adjustments are made is needed. In particular, the lack of uniformly good results suggests that the problem is to find an appropriate set of cells to run the GLS. In some sense, the GLS takes an equal percent in or out from each school. If the discrepancy is a function of class size, then it would be wise to adjust only those in the appropriate size class, rather than change all schools. One way of doing this would be to look at the weighted difference between the SASS and PSS number (students and teachers) divided by an appropriate SASS estimate for a particular group of schools. This would provide a diagnostic measure of a potential discrepancy. If an analysis is done on the set of SASS schools that make up the denominator above, it might help determine an appropriate set of cells for the GLS.

Among the other issues to consider (see section 1) is whether to jointly determine the estimate from PSS and SASS for the area portion of the private school universe. A combined area estimate might be a worthwhile improvement.

4.2.3 Improve the Adjustment of SASS.-- Some improvements in SASS and PSS processing may result from the study of GLS applications. One improvement that has arisen so far is the clear possibility (see Holt et al. 1994) that SASS edit checking could be enhanced if a GLS estimation is attempted. A subtler concern is the treatment in SASS of the very largest schools, when these become nonrespondents. Here perhaps a "mass imputation" rather than a weighting approach may be preferred; the PSS data could be used as a starting point. Among schools above a given size, this could have more benefit in reducing SASS mean square error than GLS.

There is a real need to explore other adjustments to SASS to capitalize on the fact that PSS and SASS were fielded for the same year. An Olkin-type estimator (Olkin 1958), for example, might be worth looking at, perhaps in combination with the GLS approach taken here (and using a method like that sketched in subsection 4.2.2 above to choose a way to group the SASS estimates).

The use of alternative GLS estimators in Deville et al. 1993 may also warrant examination. This is not seen as likely to improve much on the modified GLS approach suggested by Burton 1989, but it could be tested, especially in combination with other ideas listed above.

4.2.4 Other Considerations.-- Still other concerns need to be considered, even if the present modified GLS method were judged desirable, and could be made routine. Among these are the cost in time and money of applying GLS. So stay tuned.

REFERENCES

Bankier, M. (1992), "Two-step Generalized Least Squares Estimation in the 1991 Canadian Census," in *Proceedings of the Section on Survey Research Methods*, American Statistical Association.

Broughman, S., Gerald, E., Bynum, L. and Stoner, K. (1994) Private School Universe Survey, 1991-92, National Center of Education Statistics, *Statistical Analysis Report NCES 94-350* Washington, DC: U.S. Department of Education.

Burton, R. (1989), Unpublished Memorandum, National Center for Education Statistics.

Casady, R. and Valliant, R.(1993), "Conditional Properties of Post-Stratified Estimators under Normal Theory," *Survey Methodology*, 19, 183-192.

Cleveland, W. (1993), *Visualizing Data*, Summit, New Jersey: Hobart Press.

Deming, W.E. and Stephan, F.F. (1940), "On a Least Squares Adjustment of a Sampled Frequency When the Expected Marginal Tables are Known," *Annals of Mathematical Statistics*, 11, 427-444.

Deville, J.C., and Särndal, C.E. (1992), "Calibration Estimators in Survey Sampling," *Journal of the American Statistical Association*, 87, 376-382.

Deville, J.C., Särndal, C.E. and Sautory,O. (1993), "Generalized Raking Procedures in Survey Sampling," *Journal of the American Statistical Association*, 88, 1013-1020.

Fuller, W., Loughin, M., and Baker, H. (1994), "Regression Weighting in the Presence of Nonresponse with Application to the 1987-1988 Nationwide Food Consumption Survey," *Survey Methodology*, 20, 75-86.

Hansen, M., Hurwitz, W., and Madow, W. (1953), *Sample Survey Methods and Theory*, New York: Wiley.

Holt, A., Kaufman, S., Scheuren, F. and Smith, W. (1994), "Intersurvey Consistency in School Surveys," Paper presented at the 1994 Joint Statistical Meetings, Toronto, Canada.

Holt, D. and Smith, T.M.F. (1979), "Post-stratification," *Journal of the Royal Statistical Society, Series A*, 142, 33-46.

Huang, E. (1978), *Nonnegative Regression Estimation for Sample Survey Data*, Unpublished PhD Dissertation, Iowa State University.

Imbens, G.W. and Hellerstein, J.K. (1993), "Raking and Regression," *Discussion Paper Number 1658*, Cambridge, MA, Harvard Institute of Economic Research, Harvard University.

Ireland, C.T. and Kullback, S. (1968), "Contingency Tables with Known Marginals," *Biometrika*, 55, 179-188.

Kaufman, S. and Huang, H. (1993), "1990-91 Schools and Staffing Survey: Sample Design and Estimation," *Technical Report NCES 91-127*, Washington, DC: U.S. Department of Education.

Little, R.J.A. (1991), "Post-Stratification: A Modeler's Perspective," in *Proceedings of the Section on Survey Research Methods*, American Statistical Association.

Little, R.J.A. and Wu, M. (1991), "Models for Contingency Tables with Known Marginals When Target and Sample Populations Differ," *Journal of the American Statistical Association*, 86, 87-95.

McMillen, M. and Benson, P. (1991), Diversity in Private Schools, *Technical Report NCES 92-082*, Washington, DC: U.S. Department of Education.

Oh, H.L. and Scheuren, F. (1978a), "Multivariate Raking Ratio Estimation in the 1973 Exact Match Study," in *Proceedings of the Section on Survey Research Methods*, American Statistical Association.

Oh, H.L. and Scheuren, F. (1978b), "Some Unresolved Application Issues in Raking Ratio Estimation," in *Proceedings of the Section on Survey Research Methods*, American Statistical Association.

Olkin, I. (1958), "Multivariate Ratio Estimation for Finite Populations," *Biometrika*, 45, 154-165.

Särndal, C.E., Swensson, B. and Wretman, J. (1992), *Model Assisted Survey Sampling*, New York: Springer-Verlag.

APPENDIX
MEDIAN GLS APPROACH

As noted in the main body of this report, generalized least squares estimators can have many forms. This is true even within the specialized set of constraints that are to be imposed on the SASS. One alternative that offered promise is to divide the SASS observations at the median value of the teachers t_i and then divide the SASS cases yet again at the median of the students s_i. Four groups are thus formed

t_i, s_i both below median — t_i above median; s_i below

t_i below median; s_i above — t_i and s_i both above

An adjustment algorithm is developed by applying the intuitive idea that, for example, if SASS student estimates are too small, then there are not enough large schools in the sample and thus those above the median should be reweighted up, by say $(1+\beta)$.

To keep the number of schools fixed, an equal but opposite adjustment $(1-\beta)$ is required for those schools below the median number of students. Similar considerations apply to an upward or downward adjustment of $(1+\alpha)$ or $(1-\alpha)$ for SASS teacher estimates.

Unlike the modified GLS method in the main report, this "median GLS" is iterative and requires repeated application of the adjustment process: first to the student totals, then to the teacher totals, and so on. Each adjustment is to be made to the new cell totals derived from the previous adjustment(s). To fix the specifics here, a detailed illustration is given using the same illustrative data as earlier (see section 2.2).

1	1	1	1	1	1	1	1	1	1
1	2	3	4	5	6	7	8	9	10
1	6	2	7	3	8	4	9	5	10

Aggregating the three SASS components yields

10
55
55

Now suppose the PSS totals for this subgroup are

10
50
50

The SASS school total has already been set equal to that in the PSS so that the example starts where a standard SAS estimation procedure might end.

In carrying out the "median GLS" method, the data are divided at the median for both teachers and schools. When this is done, the resulting data are arrayed as

1 1	1 1 1
7 9	6 8 10
4 5	8 9 10

1 1 1	1 1
1 3 5	2 4
1 2 3	6 7

The corresponding cell totals are

2 3
16 24
9 27

3 2
9 6
6 13

To bring the second SASS component in line with the second PSS component, an adjustment of the form below is made.

2	3
$(1+\alpha)16$	$(1+\alpha)24$
9	27

3	3
$(1+\alpha)9$	$(1+\alpha)6$
6	13

Solving for α.

$$\alpha = \frac{50-(16+24+9+6)}{(16+24)-(9+6)} = -1/5.$$

Substituting this value for alpha yields the following new cell totals

1.6	2.4
12.8	19.2
7.2	21.6

3.6	2.4
10.8	7.2
7.2	15.6

and the corresponding overall totals have become

10.0
50.0
51.1

To bring the third (student) SASS component in line with the hypothetical PSS total, the adjustment proceeds this time by columns where

1.6	2.4
$(1+\beta)$12.8	$(1-\beta)$ 19.2
7.2	21.6

3.6	2.4
$(1+\beta)$10.8	$(1-\beta)$ 7.2
7.2	15.6

Solving for β the expression obtained is

$$\beta = \frac{50-(21.6+15.6+7.2+7.2)}{(21.6+15.6)-(7.2+7.2)}$$

$$= -1.5/22.8 = -0.066.$$

After the adjustment, the new overall totals have become

10.2
49.8
50.0

The school totals are slightly out of balance and themselves may need adjustment; notice, too, that the teacher totals are off a bit, but the gap is still smaller than the gap for students that was just removed. Continuing to cycle here would eventually yield SASS estimates that agreed to whatever closeness was desired with their corresponding PSS counterparts.

What then are the impacts on the weights, assuming the iteration was stopped at this point? The adjustments are

$$(1+\alpha)(1+\beta) = (0.800)(1.066) = 0.853$$

$$(1+\alpha)(1-\beta) = (0.800)(0.934) = 0.750$$

$$(1-\alpha)(1+\beta) = (1.200)(1.066) = 1.280$$

$$(1-\alpha)(1-\beta) = (1.200)(0.934) = 1.120$$

As noted earlier, one measure of the weight variation caused by imposing these constraints is to calculate the average sum of squared weights. In this case, that sum turns out to be approximately

Modified GLS = 10.38

Median GLS = 10.56

or not much greater than the sum of the unadjusted squared weights (at 10.00). In other words, there is not much to choose from between the two methods.

Further Considerations

The median GLS method just described was tried on two of the typologies in the SASS private school component. For the first of these, the Catholic Private component, the technique worked reasonably satisfactorily, but for the second typology, the Nonsectarian Special Emphasis component, the algorithm did not converge. Apparently, when negative weights arise in the modified GLS (used in the main body of this report), the median GLS may not converge due to the inconsistency. Because of this experience the approach was abandoned.

Listing of NCES Working Papers to Date

Number	Title	Contact
94-01	Schools and Staffing Survey (SASS) Papers Presented at Meetings of the American Statistical Association	Dan Kasprzyk
94-02	Generalized Variance Estimate for Schools and Staffing Survey (SASS)	Dan Kasprzyk
94-03	1991 Schools and Staffing Survey (SASS) Reinterview Response Variance Report	Dan Kasprzyk
94-04	The Accuracy of Teachers' Self-reports on their Postsecondary Education: Teacher Transcript Study, Schools and Staffing Survey	Dan Kasprzyk
94-05	Cost-of-Education Differentials Across the States	William Fowler
94-06	Six Papers on Teachers from the 1990-91 SASS and Other Related Surveys	Dan Kasprzyk
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